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ABSTRACT

Emerging and potential Australian industries were surveyed to identify the skills needed by their current and future workers and to determine how Australia's vocational and training (VET) system can best respond to those skill needs. The study investigated industries emerging from the work of Australia's Co-operative Research Centres program. The main data collection activities were as follows: consultations with experts; a literature review; surveys of the VET centers and their annual reports; case studies of selected centers; and case studies of new firms established by two centers. The study established that, whether oriented primarily toward new or existing industries, most cooperative research centers were working to create innovations such as new technologies, processes, tools, equipment, or products. The study documented the need to build and strengthen links between the VET sector and the cooperative research centers to achieve the following goals: (1) improve the timely flow of new knowledge into the VET sector; (2) enable centers to utilize VET's strong links with industry; and (3) promote teacher currency through professional development opportunities for VET personnel within the cooperative research centers. (Twenty-seven tables/figures and 45 references are included. Lists of the cooperative research centers and consultants are appended, along with the survey of annual reports pro-forma and the phone interview protocol.) (MN)

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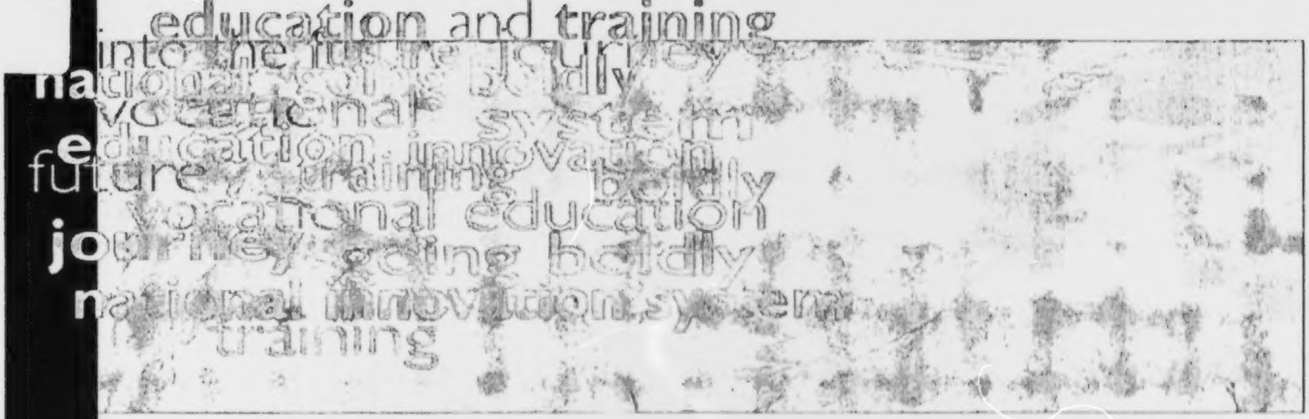
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A VET journey into the national innovation system

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The case studies from this project are available online from the NCVER website <http://www.ncver.edu.au>. A companion volume based on the same study, *Going boldly into the future: Skills and Australian high technology start-up firms*, by Karen Whittingham, is also available from the NCVER website.

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Karen Whittingham
Project manager and centre director, TAFE Industry Partnership Centre
November 2001

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Preface

This summary report presents the findings of a project funded by the National Research and Evaluation Committee: 'The skill needs of emerging industries and mechanisms for response by VET systems'. The project was undertaken in 2000–2001 by the TAFE NSW Industry Partnership Centre and the Monash University–ACER Centre for the Economics of Education and Training, in collaboration with the Australian Photonics Co-operative Research Centre. Those participating were Karen Whittingham (project manager), Fran Ferrier and Clifford Trood.

The report comprises this summary and a set of case studies of the co-operative research centres and their emerging companies.

In this volume:

- Chapter 1 defines an 'emerging industry'. It describes the boundaries of the project, the methodology and some of the results obtained from each of the project's activities. It thus can be read as a summary of the work and its findings.
- Chapter 2 presents the main findings of the report.
- Chapter 3 tells the story of the interaction between the Australian photonics industry and the NSW TAFE Industry Partnership Centre that was the inspiration for the project.
- Chapter 4 uses material from a review of the literature, illustrated by examples from project material, to discuss methods of forecasting skill needs, general trends in skill needs and predictions of the skill needs of emerging and new industries. It briefly discusses some implications for vocational education and training (VET).
- Chapter 5 looks at how the research and development being undertaken in the co-operative research centres contributes to new and changed skill requirements in industry.
- Chapter 6 documents the connections and disconnections between organisations and people in the VET sector and the co-operative research centres. It highlights some barriers preventing better connections and some consequences of both good and poor connections.
- Chapter 7 discusses the linear diffusion model now being used in the national innovation system and which is based on parcelling up and handing on new information from the national innovation system to industry and other stakeholders, including VET. It also suggests a new, more effective model for ensuring a flow of new knowledge into the VET system.
- The final chapter offers some conclusions and sets out some objectives for the future and strategies for achieving them. These need to be considered in the context of developments in the VET sector since the research behind this report was completed.

The case studies from the project provide details of some early-stage, new and mature industries which are undergoing significant change as a result of new market demands, new technologies, other tools or process improvements. All the cases reported arise from research and development work carried out in the co-operative research centres that form part of the national innovation system.

The skill needs of all the companies so far created as a result of the work of the Australian Photonics Co-operative Research Centre and the Co-operative Research Centre for Molecular Engineering and Technology are fully described in a companion publication by Karen Whittingham, *Going boldly into the future: Skills and Australian high technology start-up firms*. The latter centre could be classified into the medical diagnostics industry but is distinguished from the rest by its use of biotechnology.

Executive summary

This project sought out emerging and potential Australian industries to find out what skills their workers require, both now and in the future, and to identify if, how and when the vocational education and training (VET) system can best respond to these skill needs. It was limited to investigating industries emerging from the work of one sub-section of the national innovation system—the Co-operative Research Centres program.

The project consisted of a number of different activities:

- consultations with experts
- a survey and review of the relevant literature
- a survey of the annual reports of the centres
- a telephone survey of the centres
- case studies in selected centres
- case studies of new firms established by two centres.

The study found that among the co-operative research centres new industries are already apparent in photonics and in the environmental areas of renewable energy, waste management and de-salinisation ('saltonics'). A future new industry is likely in satellite systems. In addition, a number of the centres are working toward the re-creation of existing industries. These include several that are working towards re-forming existing industries on a sustainable basis, particularly in agriculture and tourism. Further potential for new industries exists also around the products, tools and processes that will be the outcomes of the centres' research and development programs, e.g. agricultural machinery, diagnostic systems.

Whether oriented primarily to a new or to an existing industry, most co-operative research centres are working to create innovations such as new technologies, processes, tools, equipment or products. Some of these innovations will lead to requirements for some new skills, or contextualised skills, as they are applied in industry or enter production. The VET sector could play a part in meeting at least some of these skill needs, particularly where low- to medium-level technical level skills are required.

However, not all innovations will lead to changed or new skill requirements. A new product, for instance, may simply add a line to an existing suite of products. New or updated skills will be required only where there is a significant difference between the innovation and whatever it replaces or complements.

Some innovations are competency-destroying because they replace, rather than amend, whatever already exists. This is the case with some new technologies, and in these cases skill requirements may change substantially. Sometimes a new tool or system will simplify a task that previously could be performed only by experts. These innovations free up experts for more creative work and enable workers with lower-level skills to take on tasks that previously required more expertise.

When assessing whether new or upgraded skills will be needed as a result of the adoption or implementation of an innovation it is important to consider the particular characteristics of the innovation carefully and to compare it with what already exists. In some cases workers may only need to make minor adjustments. In others, more radical initiatives will be required.

Not all skill needs arising from the innovations created by the co-operative research centres require a formal response from education and training systems. In the case of the existing industries that are connected with the centres, as long as the number of workers required to have new skills is small, the centres themselves are often able to meet the demand for training/re-training through the industry seminars and workshops that are part of their education and training programs. However, when many workers with new skills are needed, the centres do not have the capacity to meet demand.

The time required to develop appropriate programs and materials and the capabilities of staff to deliver new courses means that planning to deliver VET should ideally start well in advance of the point where the training is required. This possibly lengthy process would be expedited if the VET sector were familiar with the work being done in the centres and its potential to create new skill requirements and also if the centres recognised the interest of the VET sector in their work and its outcomes and acted to include it in their activities.

Currently, the new knowledge created in the co-operative research centres does not always reach the VET sector. There is no systematic process supporting the flow of information between the two and the links that do exist are often weak or informal. Thus, co-operative research centres are often unaware of VET sector interest in what they are doing and knowledge of the work of the centres may be uneven in different parts of the VET sector—even where this work is likely to lead to innovations that will clearly require a VET response.

Where the links between the VET sector and the co-operative research centres are strongest, benefits flow to both sides. For the centres, connections with the VET sector provide access to new networks and extensive experience in working with industry. As new skill needs arise, they can be dealt with more quickly and effectively. VET links can also bring in specialist expertise and enable access to specialised equipment and other facilities. For VET organisations, benefits from connecting with a co-operative research centre include additional opportunities for staff personal and professional development through participation in research and development, or in the co-operative research centre's education and training program. The organisation will gain access to the new knowledge that it needs to ensure that its teaching remains up to date. It will have information that will enable it to identify new opportunities for fee-for-service provision.

The places where strong links currently exist provide the basis for constructing effective models for VET–co-operative research centre interaction. While no single model is suitable for all occasions, each demonstrates some 'best practice' features that others could usefully emulate. None of these connections is working perfectly. In each case some difficulties have arisen—usually through a lack of knowledge or misunderstanding However, in each case the benefits of the relationship also are clear.

The development of stronger links between the VET sector and the co-operative research centres should be pursued as beneficial to both and to the industries they serve. Ideally, the centres should not merely consider VET as a 'recipient' of their research outcomes, although recognising the VET sector's interest in their work would be an advance in some cases. This would limit the benefits that could be derived from the connection and would not support timely attention to new training needs. Rather, the VET sector should participate where possible and appropriate in the activities of the co-operative research centres—in the knowledge creation process as well as in the centres' commercialisation and dissemination and education and training programs. Only through the mutual knowledge and understanding that will arise from a close relationship of this sort will the full range of benefits be achievable.

Kadence, a spin-off company of the Photonics Co-operative Research Centre, recognises these benefits, preferring to use TAFE colleges and staff in the development of a high volume, automated packaging and manufacturing technology for the photonics industry.

An objective for the future should be *to build and strengthen the links between the VET sector and the co-operative research centres in order to:*

1. Improve the timely flow of new knowledge from the co-operative research centres into the VET sector to support planning for the delivery of VET to meet the skill needs arising from the adoption of centre-created innovations in existing industries and the creation of entirely new industries.
2. Enable the centres to make use of the strong VET links with industry (including in the design and delivery of training), the facilities of VET sector organisations and the skills and expertise of VET personnel.
3. Promote teacher currency in VET through professional development opportunities for VET personnel within the co-operative research centres.

A commitment by both the VET sector and the centres will be needed to achieve this objective and will require action by many people and organisations. A leadership role taken in the VET sector by the Australian National Training Authority, state and territory training authorities and some registered training organisations would assist this process. There is also considerable potential for industry training advisory bodies to play a stronger part in improving the flow of knowledge between co-operative research centres and VET planners and providers, particularly in the case of existing industries.

Chapter 1: A VET journey into the national innovation system

Introduction

Australia has an unfortunate reputation as a nation of good ideas not realised. History tells many stories about the nation's failure to support the work of researchers and inventors and to develop and successfully commercialise the 'widgets', tools, processes and other ideas they have for improving existing industries—or for whole new industries. Too often, good ideas have simply disappeared or have been forced offshore to find the expertise and resources they need.

Traditionally, Australia has relied heavily for its economic success on exploiting its natural resources, and thus on industries such as agriculture and mining. However, in the developing global knowledge economy many of our traditional industries are in decline and there is a new urgency to find other sources of employment and earnings. The need to encourage and nurture new ventures is becoming critical. Australia now has no choice but to break the patterns set in the past and to act swiftly and boldly to support good ideas and the new and changed industries that they create.

With this in mind we set out on a project to seek out new industries (or potential for new industries) emerging in Australia, to find what underpinning knowledge and skills they require now of their workers and will in the future, also to identify if, how and when the vocational education and training (VET) system should best respond to their skill needs. Our project was driven by not only the imperative to meet the needs of new industries if they are to prosper and grow, but also by another vital concern—that vocational education and training in Australia should remain current, relevant and useful in a changing world.

Over many years VET has proven itself of value to Australia's traditional industries, providing the skilled workforce necessary for these industries to prosper. Since the late 1980s changes to the VET system have sought to increase its flexibility and responsiveness to the needs of these industries. However, what of the future? As some industries decline, others reinvent themselves and new industries emerge, will VET also need to change? What roles can it take on? What challenges will it face and how can it respond?

The idea for the project sprang from the experiences of the New South Wales TAFE Industry Partnership Centre in encountering and responding to the fledgling Australian photonics industry. Difficulties and problems arose which showed clearly that VET has a critical role in assisting this new industry, but also that its involvement began almost too late. They highlighted how the cutting-edge research organisations that comprise Australia's national innovation system are effectively structured in a way that tends to neglect VET. In addition the problems showed that the VET system's close connections with, and focus on, existing industries leaves limited room to consider the new.

What is an 'emerging' industry?

All existing industries were new once. They have also always presented a challenge to those anxious to ensure their success.

In Australia, new industries are supported at the national level through the federal government's Department of Industry, Science and Resources (DISR).[1] The department's relatively young Emerging Industries Section identifies, assesses and facilitates the development of emerging industries and provides policy advice to government. In this work it has adopted a definition of emerging industries developed by Michael Porter:

> Emerging industries are newly formed or re-formed industries that have been created by technological innovation, shifts in relative cost relationships, emergence of new customer needs, or other sociological (and environmental) changes that elevate a new product or service to the level of a potentially viable business opportunity.
>
> Michael Porter 1980

Porter's definition highlights the many different sources from which a new industry can spring. Technological developments are not the only changes that can lead to a new industry and not all emerging industries are 'high tech'. The Department of Industry, Science and Resources (1999) tells us that the boundaries between emerging and traditional industries can in fact be very fluid so that when we ask 'What are emerging industries?' we must also consider innovations in process, knowledge infusion in traditional industries and opportunities for new and old technologies to converge.

Many of the industries emerging at the end of the twentieth and beginning of the twenty-first centuries are the outcome of the development of an innovative or original technology. The Emerging Industries Section of the Department of Industry, Science and Resources, together with CSIRO conducted a forum in 1999 where stakeholders of emerging industries identified several new technologies that it believes are likely to have a major impact on science and business. These include information technology, bio-technology, nano-technology, micro-electronics, telecommunications (including photonics), environmental management and materials technology. Given their technological basis, many early stage industries are thus often referred to as 'emerging technology industries'.

The Department of Industry, Science and Resources points to three types of technological innovation that are shaping new industries in different ways. *Base technology* is a technology that is essential, but offers little potential for competitive advantage. *Key technology* is the most critical to competitive success because it offers the opportunity for product or process differentiation; and *Pacing* or *enabling technology* has the potential to change the entire basis of competition but has not yet been embodied in a product or process. Innovations in pacing technology can take a very long time to produce a new process or product. Australia is noted to have a competitive advantage in some technologies that will support new industries, but not in others (DISR 1999).

According to Porter emerging industries face particular difficulties because they operate where there are no established rules to the game. They need to establish rules that will allow them to compete and prosper. The Department of Industry, Science and Resources recognises other key characteristics of emerging industries as:

- **low predictability**: they are difficult to foresee, but obvious in hindsight.
- **rapid growth**: but they often result from high intensity research and development and have a lengthy gestation.
- **large and small firms**: there are new firms, spin offs and existing firms entering new areas of business.
- **reliance on highly-skilled people**: there is need to anticipate future skills sets and requirements. There is a diversity of skills and merging of occupational boundaries.

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[1] The Commonwealth Department of Industry, Tourism and Resources in 2002 took over most functions of the Department of Industry, Science and Resources.

- **fragmented unstable markets:** diverse products, frequent product changes. A growing number of firms have wildly fluctuating market shares.
- **'probe and respond' approach:** products and needs are not clearly defined, requiring rapid feedback/feed-forward between product and market.
- **fluid/turbulent**: experimental/dynamic operational styles.
- **global focus:** they may be 'born global'.
- **unconventional associations:** they may be capability based. (DISR 1999, p.8)

Emerging industries require different skill sets and are marked by a diversity of skills and a merging of occupational boundaries. These are particularly important considerations for this project. Skills required may be generic, common to several or even many occupations and industries, old or new. In these cases, specialist training for one industry or occupation may not be required. Some required skills may be so specialised and advanced that they are beyond the current scope of the VET system and (under current arrangements) more properly the responsibility of the higher education system. Some skills may build on an existing knowledge base and thus can be added as an advance or refinement of existing skills. Others might first require the acquisition of completely new knowledge.

Workforce skills will be one of the 'critical success factors' for emerging industries such as photonics in the next decade, but there is a five-year time lag before 'the education sector responds to industry's needs for people skilled in a particular area' (DISR 1999, p.10). Reducing the time lag between when a skill need is first recognised and when the skill becomes available in the workforce must thus be a priority for Australia if it is to support and nurture its new industries. Ensuring that VET can help to meet the skill needs of emerging industries in a timely fashion presents another challenge for this project.

The project boundaries

Time and budget restrictions limit what and how much can be done in any research project. We were limited to investigating only industries emerging from the work of one sub-section of the national innovation system—the Co-operative Research Centres program.

Innovation is the process that incorporates knowledge into economic activity. It is both the process of transformation of an idea into a marketable product or service, and the resultant new product, process or service. Innovation extends beyond the confines of the research and development laboratory and encompasses the turning of new ideas into competitive advantage (DISR 1999). Australia's national innovation system incorporates:

- federal and state governments and their advisory bodies and policy and program development departments
- a legal and regulatory framework (IP Australia)
- promoting and supporting organisations (e.g. AusIndustry, the Australian Research Council and the National Health and Medical Research Centre, co-operative research centres, the R&D tax concession)
- public education and research organisations (TAFE, universities, Commonwealth and state government research organisations, research and development performing firms, private non-profit research organisations)
- linkages and technology diffusion (e.g. technology parks)
- venture capital programs.

Australia's national innovation system has some strengths but it also has some weaknesses. It remains highly fragmented, with few linkages and little active co-ordination across players. Industry self-funded research and development is relatively low, reflecting a traditional focus on unprocessed agricultural products and minerals. Educational and research infrastructure and institutions produce significant benefits to the country and enjoy an international standing but higher levels of investment will be necessary to keep pace with future international standards and capabilities. Australia's science and technology base is still oriented toward the agricultural and earth sciences and needs to be broadened to meet the demands of a technology-based export-oriented economy. A significant proportion of Australian firms do not currently innovate and a low average firm size is associated with a decreased ability to compete in export markets and a lower propensity to innovate (DISR 1999).

The Co-operative Research Centre program represents a small, but crucial element in the national innovation system. Mathews and Howard (2000), describe it as 'a major platform for Commonwealth support for industrial research and development and particularly for supporting more general public interest research concerned with identifying and diagnosing problems—particularly in the environmental area. It has an important role in supporting and promoting public-private linkages (DISR 1999).

These centres were chosen for this study for several reasons. Firstly, a broad sweep to detect industries emerging from many different sources would have duplicated work being undertaken in the Department of Industry, Science and Resources and precluded detailed work. We preferred to take a closer look at industry-focussed areas so that we could explore the issues for VET more deeply.

Secondly, the Co-operative Research Centre program is unique in the national innovation system in its strong commitment to applied research and to the implementation and/or commercialisation of the research outcomes. This provides a fertile environment for the emergence of new industries. *Applied research* is undertaken usually in response to a specific problem or difficulty and thus differs from *basic research,* which is often motivated by curiosity. Though the boundaries between the two types of research are often blurred, and both can lead to outcomes such as new tools, systems or processes, the relationship between research and a specific outcome is likely to be more direct in the case of applied research. The time span is also likely to be shorter from research to final product development and application.

The main aim of the Co-operative Research Centre program is to strengthen collaboration between researchers, research organisations and research users in order to 'obtain better value from Australia's investment in research and development' (Mercer & Stocker 1998). It does this by promoting long term co-operative relationships between researchers and research groups from universities, government research laboratories (Commonwealth, state and territory), and the private sector. The relationships promote a flow of knowledge and ideas in both directions so that the research can seek answers to current problems. End-user involvement in the research also speeds up dissemination of results and implementation of new products or processes.

Thirdly, the TAFE NSW industry partnership centre had already worked closely with the Department of Industry, Science and Resources, the Australian Photonics Co-operative Research Centre, and also the Co-operative Research Centre for Intelligent Manufacturing Systems and Technologies. It was therefore familiar with the structure of the national innovation system, the centres, the ways in which they operate, and some of their main concerns especially in relation to future skill needs and links with VET. The knowledge gained through this connection would give the project a 'head start'.

Fourthly, these centres offer considerable scope for research. There are many of them (the exact number varies depending on expiries, renewals and new entrants but is usually over 60) and they work in six different fields (see table 1.1 below). They are also large (although they can vary considerably in size) with an average budget of $7 million per centre per year, each supporting about 30 full-time research staff and several research programs.

The disadvantage of limiting our work to the co-operative research centres was that it prevented us from fully exploring industries emerging from other sources. We were able to capture these only so far as they were represented and discussed in the literature reviewed for the project.

Table 1.1: Co-operative research centres by field of research, mid-2000

Research field	Number of centres
Manufacturing	9
Information and communication technology	6
Mining and energy	10
Agriculture and rural-based manufacturing	14
Environment	15
Medical science and technology	10
Expired	3
Total co-operative research centres	**67**

Source: www.disr.gov.au/crc/centres

The project methodology

The project consisted of a number of different activities, each of which yielded information useful in developing and constructing the activities that followed it. The activities were:

- consultations with experts
- a survey and review of the relevant literature
- a survey of the annual reports of the centres
- a telephone survey of the centres
- case studies in selected centres
- case studies of the companies spun out of the centres.

This methodology allowed the data acquired in one stage of the project to inform the next stage. For instance, the review of their annual reports identified centres (both individually, and in selected groups) that would make particularly interesting or representative case studies and the major questions and issues that should be taken up. This method allowed the team to drill progressively deeper into the material being collected.

Each activity was underpinned by eight research questions:

1 Which research and development areas are most likely to create a demand for training in Australia?

2 What forms of industries are likely to arise from research and development?

3 Are there common factors across emerging industries that will have a bearing on the forecasting of training need and demand?

4 Do emerging technology companies have skill needs that are similar to those required in established industry? Or is there/will there be a requirement for a new type of knowledge technician/worker?

5 What approaches to training are taken by emerging technology companies?

6 How (if at all) does the VET sector currently intersect with the Australian government-funded research and development sector in order to determine skill needs in emerging industries?

7 What does the research and development sector believe are effective strategies to enable VET practitioners to make the essential connections and meet training need and demand in a timely fashion?

8 What models of collaboration or partnership between research and development and the education sectors will be required to ensure the supply of skilled knowledge workers for industry?

Consultations

In the project's early stages, consultations with individual experts dealing with innovation, research and development and new industries from a variety of perspectives in government, industry and research organisations confirmed that the project was timely and was exploring some hard questions. Concern was often expressed about support for new industries. Skill needs were a sore topic: what these needs might be (now and in the future); the difficulties in predicting future needs; likely problems if they were not met and what could be done to make sure they were addressed. No simple answer was offered and there seemed to be a general belief that these were very difficult and complex issues. In particular, we were struck by a common perception that accurate predictions of skill needs in new and changing industries are extremely difficult to make because of the many factors affecting the growth and success of an industry. This was a strong theme also in the literature and was borne out in several of the case studies.

The potential of the VET sector to support new industries was also recognised in the consultations. The failure to include VET formally in the national innovation system was acknowledged as a weakness of the system that impeded the assessment of VET-level skill needs arising from research and development and slowed the process of developing training programs to meet these needs.

The literature review

The literature review had four specific aims:

- obtaining contextual material about the current major social and economic changes affecting the nature and organisation of work and skill requirements
- clarifying the meaning of an 'emerging industry' and identify some recognised emerging industries and the forces that had created them
- indicating approaches to evaluating skill needs and their usefulness
- providing an indication of some ways in which these needs were being addressed.

The literature examined included publicly available English language material in print and in electronic form, from Australia and overseas. For reasons of scale and accessibility, material on video, and documents not publicly available were excluded.

In general, we found that the literature addressed many of the major questions underpinning the research project, particularly changing skill needs and the forces driving them, but there were some gaps. The most effective methods for measuring and forecasting skill needs were much debated. There was considerable material about globalisation, the shifting balance between generic skills and technical/specific skills, the effects of technology and occupational change. There were also some useful resources on the nature of emerging industries and their potential for growth. However there was much less material that specifically dealt with the nature of appropriate responses to these skill needs by the VET sector and providers. While there was considerable agreement that *something* needed to be done, there was much less information about *what* this ought to be.

The literature in Australia and other industrial nations identified two major trends across existing industries in requirements for skills: a growing demand for higher-level skills and an increasing emphasis on generic skills and attributes, though technical and specific skills remain important. The major factors identified as causing these changes were globalisation and the development of new technologies. The literature described the growth of a 'knowledge economy' in which workers need to be more highly skilled and committed to lifelong skill development. It forecast that workers would work in flexible organisational structures and engage in knowledge networks. In this environment, industries and enterprises will need to respond quickly to market opportunities and challenges if they want to be successful, maximising efficient use of technological innovation and internationalising their ideas. Through continuous learning workers and enterprises will strive to avoid technical obsolescence.

Review of annual reports

Under the terms of its funding agreement with the Commonwealth, each co-operative research centre is required to provide an annual report of its activities to the Co-operative Research Centre Secretariat. The report is used to monitor its performance and thus must include data against some key performance measures including funding sources, expenditure, staffing and activities such as commercialisation (e.g. research projects completed, patents applied for). The reports detail the operation of the centre over the preceding financial year, and plans for the next year. Many centres also use the reports as a means of disseminating information about their work, so many contain substantial information additional to that required for the Commonwealth's purposes.

As a first step towards understanding the nature of the work being undertaken in the centres, we surveyed the most recent annual report produced by each centre. The main aim was to obtain basic information that would give an indication of the centres' research programs and their objectives, any progress achieved, the development of any new products or processes and whether they were being applied in existing industries or would form the basis for a new industry. We also wanted to find any formal links between the centres and people or organisations in the VET system. A third goal was to uncover interesting cases for further study.

A major finding of this review was that most centres were engaged in gradual rather than rapid innovation and were oriented to achieving improvements in existing industries rather than producing technologies, products or processes for new industries or markets. The potential for the emergence of new industries, at least within the next five years, appeared very limited.

However, there were indications that if the products and processes coming out of the centres' work were applied in existing industries they would still require some new or different skills. Many of the centres acknowledged that their work would lead to some existing skills becoming obsolete, and requirements for new skills, though few gave details of the specific changes likely, or attempted to quantify them. Often the reports gave the impression that the issue of skill needs was too far down the track, or too remote, for those engaged in, or with, the research to give it much attention. This was reinforced by the fact that industry training advisory boards, private registered training organisations and TAFE colleges were rarely represented among the centres' partners or associates.

Each report provided information about several research programs within which were a number of projects. Close examination of the research programs indicated that overall about 60% were being conducted in areas where there was an existing VET program. The extent of this crossover varied from one research field to another, but was highest in environment and information and communication technology and lowest in mining and engineering (table 1.2 below).

In spite of this, few centres documented any connections with either individuals or organisations within the VET system. There was little evidence of awareness that their work might have implications for VET, or that VET involvement could make a useful contribution to it. The majority of research programs identified possible 'end-users' of the research outcomes and often involved them in the centre's work, but rarely considered VET. Only one of the centres (Australian Photonics) had a VET organisation among its partners, less than a handful had VET associates and a small number were very closely connected with Aboriginal communities and engaged with VET as a result. Given the VET system's close links with industry, its neglect was particularly marked.

Table 1.2: Research programs in the co-operative research centres and their relevance to VET programs by field

Research field	Relevant to VET programs	58%
Agriculture and rural-based manufacturing	38 of 53	72%
Environment	46 of 59	78%
Information and communication technologies	19 of 26	73%
Manufacturing	24 of 37	64%
Mining and engineering	12 of 43	28%
Medical science and technology	12 of 37	32%

Co-operative Research Centre program guidelines call for substantial collaboration with industry and thus all the centres documented strong connections with a variety of players in the industries for which their work is expected to be most useful. The only exceptions to this were two cases in which centres were working in an area where there was no well-established Australian industry, that is, satellite systems and photonics. Industry partners were also often used in the commercialisation of the centre's research outcomes. As part of their dissemination and utilisation programs, several centres also offered training programs and workshops for existing industry workers.

The telephone survey

The lack of connections between the co-operative research centres and the VET system exposed by the annual report review raised an important question. Did this finding reflect inadequate reporting by the centres in their annual reports, or was there really very little VET involvement of substance to report?

If the connections were as weak as they generally appeared then there were issues that required considerable further exploration. How could information about the centres' research outcomes reach VET? How and when could VET find out about new products and processes being developed in the centres for application in existing industries? How could VET learn about possible new industries? What were the chances that the system could develop training to meet new skill needs arising from the research work of these centres?

If, on the other hand, the connections were better than reported, were there examples that could serve as a model for VET involvement in the national innovation system? Were there cases illustrating successful transmission of information about industry developments (for either new, emerging or existing industries) from the national innovation system to the VET system?

These issues were taken up in a telephone survey of the co-operative research centres in which they were asked to identify areas of skill change or new skill development at a VET-appropriate level in their industries and to comment specifically on their VET connections. Excluding centres whose terms had expired and a small number of others already chosen for deeper case studies (which were asked similar questions in the next stage of the project) 49 centres were surveyed. In all cases an attempt was made to interview both the chief executive officer and the education and training manager of the centre.

Overall the telephone survey confirmed that there were limited links between the centres and VET, but that these were sometimes stronger than suggested by annual reports and that some new connections were being developed. It also confirmed that within the centres there was often very little knowledge about the VET system, its roles, and its potential to contribute to research and development and to industry training and development. Among centre personnel there were some common misconceptions about VET that worked against links and often reflected outmoded mental/manual constructions of knowledge and work. Without any real knowledge of the system some centre officers displayed a bias against people and organisations in VET on the basis of wrong information such as 'VET staff are poorly qualified', 'VET is just about apprenticeships', or 'if we work with TAFE our status will diminish'. However, where connections existed, these attitudes were much rarer.

While the connections that did exist were generally regarded positively, the centres also indicated some problems in navigating the VET system. They had experienced difficulties due to the complex arrangements of the system. For instance:

- The Co-operative Research Centre for Materials Welding and Joining has an agreement with Wollongong College of TAFE to run technical modules in the centre's education and training program. The TAFE staff are keen and willing to run the courses for the centre but are bound by institutional protocols on cost structures and student numbers. The student numbers are low and as a result the costs of training are quite high per head.
- The Co-operative Research Centre for Intelligent Manufacturing Systems and Technology has developed a specific project aimed at VET teachers upgrading their skills. The program has been implemented in Victoria and to a lesser extent in NSW. The centre says it is a hopeless task to get directly to VET students as it costs too much, so it has decided that it is better to influence the teachers. Also it is difficult to get other centres involved in this area as they see TAFE as beneath them. There is 'an academic wall'.
- The Wool Co-operative Research Centre has developed a range of training resources but decided not to develop mainstream courses because of difficulties in the VET accreditation process.
- The Co-operative Research Centre for Weeds Management has initiated the development of a training package and had it accredited through Murrumbidgee Agricultural College. The centre commented that VET is too complicated and a nightmare for people outside the sector. Often industry does not want the qualification, but wants the outcome.

Most of the centres indicated that some of their research programs were likely to lead to a future need for VET. Of the 49 co-operative research centres surveyed:

- Little possibility of a future training need was detected in 19 cases.
- Some future training needs were likely in 8 cases.
- Definite future training needs were detected in 22 cases.

The centres least likely to create a future VET need were those working in the field of medical science and technology, but even in this field some areas of the centres' work were found to be of possible interest to VET—that is, trained laboratory technicians. In all other research and development fields there were many programs likely to lead to a training need, with a particularly strong likelihood noted in agriculture.

The case studies

From the material in the annual reports we identified several categories of co-operative research centres that would provide interesting and useful case studies. An initial selection of centres for case study within each of these categories followed the review of their annual reports but was revised after the telephone survey in light of new information. For instance, the Co-operative Research Centre for Landscape Evolution and Mineral Exploration was included when it was found that the centre's efforts, coupled with government and community support, had the potential to create an entire new industry that we dubbed 'saltonics'. (While working on projects to develop new tools or processes to improve mineral exploration technology the centre found that one of its exploration technologies also had significant application in work to combat salinisation of land and waterways.)

The categories themselves were also revised after the telephone survey. Firstly it was thought that selection of cases ought to include at least one industry from each of four stages of industry development, that is, ***future, emerging, new*** and ***mature***. Secondly, clearer distinctions needed to be drawn between different types of skill needs. With these criteria in mind centres which demonstrated few future skill needs, or skill needs of greater relevance to higher education than VET, or both, were excluded from further consideration in the project. The remaining centres fell into four main groups:

- **Big impact**: centres in areas in which significant skill needs are indicated in the future.
- **Big gap**: centres in areas in which there are current significant skills needs that are not being met by existing VET provision.
- **Narrowing gap**: centres in areas in which VET provision is currently being developed and stronger connections with the VET sector would be beneficial.
- **Watching brief**: centres in areas in which some future skill needs are possible.

In addition, the best practice category was retained for the two centres showing the strongest VET links.

The 10 co-operative research centres chosen for case studies are indicated in table 3. Some were selected because information obtained from the annual report review or telephone survey indicated that they would be able to throw light on a particular issue or aspect of our investigations. Others were chosen because they were representative of the centres within a particular category.

Overall, the case studies illustrate industries at different stages in their development, including mature industries driven to embrace change by a variety of forces. They demonstrate the faults and advantages of a number of different commercialisation, dissemination and education strategies in use by the centres. They provide much material about the many factors that affect the speed and success of the commercialisation of research and development outcomes and they demonstrate how all these things affect skill and training needs. They confirm the weakness of the links between the centres and VET, but also show that where links are stronger there are benefits to both sides.

Some strong themes emerged:

- In emerging and new industries, needs are indicated for some fairly traditional skills, but there is also a strong demand for skills to be 'contextualised', that is, understood and practised within the framework of the particular industry.
- External pressures are driving several existing industries to take greater account of social and environmental concerns. These external pressures include environmental legislation and regulation and public opinion. They are leading to a number of industries embracing the principles of 'sustainable development'. Re-establishing on a 'sustainable' footing is creating needs for new skill in fairly traditional industries (e.g. tourism and rural industries).
- Government support is critical to the development of emerging and new industries. It enables the research and development that can lead to new products and processes. It helps these industries to understand and gauge the state and nature of local and global markets for their products and services and the best ways of meeting market expectations. It is also seen by these industries as fundamental to the achievement of a guaranteed and long-term supply of the skills they need.
- The quality or merit of a new product or process plays only a small part in its success in the market—if it gets to market. The success of any industry depends on the complex interplay of many factors. A supply of required skills is one, others include access to venture capital, levels and types of government support, consumer tastes and preferences, competition, timeliness.
- Where an emerging or new industry consists primarily of small and medium-sized enterprises, diffusing new knowledge to them can be a very difficult problem. Thus industry development is slowed.

- The lack of links between the co-operative research centres and people and organisations in the VET system can in part be attributed to a lack of awareness of VET, or their misunderstanding the system. This may reflect the higher education base of the centres, who indicate that stronger links will be forged when these difficulties are resolved.

Table 1.3: Case study co-operative research centres, industry stage by skill needs

Industry stage	Big impact	Big gap	Narrowing gap	Watching brief	Best practice
Future industry				Satellite systems	
Emerging	Photonics			Landscape evolution and mineral exploration	
New industry		Waste management and pollution control Sustainable tourism	Water quality and treatment		Renewable energy
Mature industry		Cast metals			Viticulture

Case studies of high technology start-up companies

Case studies of holding and new companies (start-ups) established by the Australian Photonics Co-operative Research Centre (APCRC) and the expired/closed Co-operative Research Centre for Molecular Engineering Technology (CRC MET) were undertaken to obtain further information about skill needs and training practices in high technology areas.

The companies selected were AMBRI Ltd, and the following companies in the photonics industry: Australian Photonics Pty Ltd, Redfern Photonics Pty Ltd, Redfern Fibres–NuFern International Inc, Redfern Optical Components, Redfern Integrated Optics, Redfern Broadband Networks, Redfern Polymer Optics, Redfern Interlink, Photonics Redcentre, Kadence Photonics, Virtual Photonics Incorporated, Indx (now JDS Uniphase) and Jiangsu Fasten Photonics Co Ltd.

In each case information was sought about:

- corporate structure and management
- the stage of development of the company, ie research, development, early commercialisation, mass production
- existing staff qualification levels
- future staff qualifications profile
- worker characteristics
- factors influencing training decisions and investments
- training needs in the short and long term
- impediments to training.

Where possible the companies provided the best information available from their business plans and made estimates based on the current value of the global market, its development, their place in it, and the receipt of venture capital to ensure their growth. In some instances, companies chose not to disclose the information for reasons of commercial confidentiality.

At the outset of this study, we had intended to interview a cross-section of start-up companies connected with a number of co-operative research centres, but were unable to identify any centre other than Australian Photonics that had formed clusters of companies (or whose start-up companies were as advanced in their development). Thus although the data collected provides information about a wide range of companies at different stages of their growth, it would have been preferable to examine a larger pool of companies as this would have supplied a more robust set of insights and an opportunity to confirm the experiences of these organisations. However AMBRI Ltd, the single start-up company from the Molecular Engineering and Technology Centre, is marketing a nanotechnology sensor in the medical diagnostic market. It was included in the study to provide a contrast to the photonics experience. The data show many similarities in experiences and problems between the photonics companies and AMBRI. These suggest that the photonics experience may be representative of the broader features of the Australian business, education and training landscape.

The study confirmed that the qualifications profile and skill requirements of each company change as it develops and in line with its objectives. The companies expressed a strong need and demand for VET qualifications. Training was particularly sought in:

- technical skills in photonics and biomedical/diagnostic areas
- electrical and mechanical engineering
- production and manufacturing
- project, financial and team-based management
- recruitment and human resources
- quality assurance
- sales and marketing
- occupational, environmental health and safety.

The number of VET graduates employed by the photonics companies is currently very low, but is expected to increase in the short term. Interestingly, none anticipates a need for apprentices or trainees but most see a TAFE diploma as a minimum standard of qualification for entry to employment. Only one company indicated that it would require its recruits to hold an undergraduate degree as the minimum qualification.

Currently the companies are only sporadically involved in training activities and this varies with the stage of development the company has reached. Those in the research and development phase, or at very early stages of development, are not inclined to view training as a priority to the same extent as those about to commence manufacturing operations.

While demand for training may be high, the need is often poorly articulated and riddled with misconceptions about the training system, which is generally not well understood. Overall, the attitudes of chief executive officers and human resource managers to training and training providers were fairly positive with all respondents keen to assist in the development of such training because they perceived it as advancing the industry in Australia.

- Many companies provided workplace training and were interested in flexible modes of teaching and learning for staff, including instructors visiting the workplace. Companies expressed the importance of quality in training and the relevance of training to competitive performance.
- Most companies were concerned that the availability of skills might be insufficient for growth plans. Companies were strongly in favour of government initiatives to address this issue. Except for small and relatively new companies, they were also prepared to invest in their own training needs.

- Some companies reported that policies must ensure that skilled people would have incentives to remain in Australia, and to return to Australia after training overseas.

The case studies highlighted impediments to training that would be significant enough to affect the level of productivity in the firm and thus its success in the longer term. Companies gave two types of reasons for not investing in training: within company factors, and external factors.

External factors were:

- lack of available courses
- lack of available trainers/instructors
- cost of training and lack of government support
- lack of a cohesive industry to support cooperation between companies on training issues
- structural weaknesses in the education system in identifying and anticipating needs
- poor knowledge transfer between the higher education and VET systems.

Internal factors were:

- the stage of development of the company. If manufacturing or development processes were not in place, the skill levels of individuals could not be evaluated and thus training needs
- perceived time constraints within production deadlines
- high-level knowledge workers who could self manage and learn on the job
- knowledge transferred outside the organisation
- perceived value to the company at its point in development
- cultural bias against traditional VET providers.

The companies depend on being able to recruit people who have a broad range of skills and knowledge, but they are not aware of what the VET system can offer and the capabilities of VET graduates. As a consequence, there is a tendency for them to assume incorrectly that the system will not be able to meet their needs.

Concluding comments

In this chapter we have described the project, its objectives and each of the activities we undertook to complete it. We have noted limitations in the methodology and defined some major terms, including 'emerging industry' and 'national innovation system'. We have explained why we focussed our study on co-operative research centres and the reasons we selected certain centres and companies for case studies. In describing each of the project's main activities, we have included some information about the information we gathered and the lessons we learned from them.

In the next chapter we present the main findings of the study. These have been synthesised from the many findings arising from each of the project's several activities.

Chapter 2: Journey debriefing: Main findings

Although most of the co-operative research centres are working towards the improvement of products, processes and other innovations for existing industries, there is still considerable potential for new industries to emerge from their research and development.

New industries are already apparent in photonics, in the bio-medical field and in the environmental areas of renewable energy, waste management and de-salinisation ('saltonics'). A future new industry is likely in satellite systems. In addition, a number of the centres are working toward the re-creation of existing industries. These include several that are working to reform existing industries on a sustainable basis, particularly in agriculture and tourism. Further potential for new industries to develop exists also around the products, tools and processes that will be the outcomes of some the centres' research and development programs, e.g. agricultural machinery, diagnostic systems.

Whether they are oriented to new or existing industries, all of the co-operative research centres are creating, or will create in the future, new technologies, processes, systems, equipment, tools or products for use in these industries. As these innovations are applied, or enter production, they may create a need for some new skills—and there may be a role for the VET sector in meeting at least some of these.

Not all of the innovations adopted by an existing industry will lead to changes in the skills needed by workers in this industry. A new product, for instance, may simply add a line to an existing suite of products. A new tool, or other piece of equipment also may require only existing skills in order to be used effectively. However, new or updated skills are likely to be required where there is a significant difference between the innovation and whatever it replaces or complements.

Some innovations are competency-destroying because they replace, rather than amend, what already exists. This is the case with some new technologies, and in these cases skill requirements may change substantially. Sometimes a new tool or system will simplify a task that previously could be performed only by experts. This is happening, for example, with the implementation of some new diagnostic tools in medicine and other fields. As they are being adopted these innovations are freeing up experts for more creative work and enabling workers with lower-level skills to take on tasks that in the past required greater expertise. These technicians will require some training to perform the tasks effectively.

When a new industry is created some of the skills it requires will be generic, common to several (or more) occupations and industries. Industry-specific training may not always be necessary. However, most new industries also want some training to 'contextualise' generic skills within the new industry framework. Where the industry is based on a new technology, such as in photonics, renewable energy, waste management and 'saltonics', workers are required to have an understanding of how the technology works and can be used. This can be built on to knowledge and skills in a related field.

A formal response from education and training systems is not always required when new skills are needed due to innovations. In the industries connected with the co-operative research centres, demand for training/re-training can often be met through the industry seminars and workshops that are part of the centres' education and training programs—as long as the number of workers required to have the new skills remains small. However, when the number is greater, the centres do not have the capacity to respond and look to others, such as educational institutions and systems to assist.

The Co-operative Research Centre for Renewable Energy illustrates this. As industry demand for RE-trained workers has grown, the centre has taken steps to expand the supply of training by contracting the Renewable Energy Centre at the Brisbane Institute of TAFE to develop its Certificate IV course in Renewable Energy for flexible delivery. The centre has also sought registered training organisation status in its own right and is developing partnerships with other VET providers.

In the case of new industries, formal education and training have a stronger role in some stages of industry development than others. In the early stages they will have only a minimal role as most skill needs will be able to be met through in-house or informal training. However their role will increase as the industry advances to later stages of development. Three stages are apparent in the development of the new industries connected with the co-operative research centres:

- *A developmental stage* in which ideas/technologies are still being worked out.
- *An intermediate stage* in which planning takes place for taking new products and services to market.
- *A mature stage* in which the products and services are available on the market.

Each of these stages requires different types of skills:

- *Developmental:* The primary need in this stage is for skills in research and development to advance knowledge and to find new applications.
- *Intermediate:* The challenges of planning for successful commercialisation of new products and services require skills in management, in analysing markets and in accessing venture capital. Research and development skills continue to be required for further product refinement and new product development, but less so than in the developmental stage.
- *Mature:* Business and management skills remain important and research skills are useful for further development, but there is an increasing emphasis on lower-level and technical skills to support the manufacture, installation and maintenance of products and the provision of services.

A role for the VET sector to respond is most clearly indicated in the third stage. However, planning should ideally begin well before this stage begins, due to the time needed to prepare appropriate materials and programs and to train staff. Unfortunately though, the new knowledge created in the co-operative research centres does not always reach the VET sector early enough for this planning to happen in the best way. Currently, there is no systematic process supporting the flow of information between the two and the links that do exist are often weak or informal. As a consequence, the centres can be unaware of VET sector interest in what they are doing and knowledge of the work of the centres may be uneven (or missing altogether) in different parts of the VET sector.

Most links between the VET sector and the co-operative research centres are weak or informal. There are few strong links. This is unfortunate because where they are strongest, such as in the case of the Australian Photonics Co-operative Research Centre and the TAFE NSW Industry Partnership Centre and TAFE NSW Southern Sydney Institute, or the Viticulture Co-operative Research Centre and WINETAC (the Wine Industry Training Advisory Council), both partners can identify benefits from the relationship. Linking with VET can provide co-operative research centres with access to new industry networks, to expertise, equipment and other facilities. It can bring in training and professional development expertise and opportunities. Linking with a centre can provide VET organisations with new opportunities for the personal and professional development of staff. It enables early access to new knowledge and so gives an advantage in ensuring that teaching remains up to date. It can also lead to new opportunities to earn additional income, such as through providing fee-for-service training.

Development of stronger links is inhibited by factors including mutual misunderstanding and neglect, the complex nature of the VET sector and some practical difficulties in making the 'right' connections. However, the strong links that already exist show that these can be overcome.

The ten co-operative research centres reported in the online case studies of this report are summarised in table 2.1 below, highlighting some of these findings. The table identifies the main features of each case, notes the objectives of their research, the status and development of the industry to which their research outputs will be most useful, the skill requirements expected to arise from their work, their connections with VET and current VET provision.

Table 2.1: Summary of co-operative research centre case studies

	Landscape Evolution and Mineral Exploration (LEME)	Water Quality and Treatment	Waste Management and Pollution Control
Research	Creating tools to assist mapping, management and remediation of dry land salinity (unexpected spin-off of research program).	New tools and processes to monitor and manage water supply.	High-technology solutions for recycling and re-use of waste. Yet to be commercialised.
Industry status and development	Potential emergence of a new industry to counter dryland salinity. Driven by environmental issues and government funding.	An old industry changing rapidly as new technology is introduced. Changes being driven by environmental considerations.	Fragmented industry experiencing significant change due to change from low-tech to high-tech solutions.
Skills demand	Geophysicists and related mineral exploration including mapping, data collection and interpretation.	Skills to operate new tools and processes.	High-tech tools operation and maintenance and new management approaches.
VET links	Strong relationship with Canberra Institute of Technology.	Co-operative research centre is aware that VET provides an important entry point for developing industry operational knowledge and skills.	None currently but centre would be interested in what resources a link would bring.
Current VET provision for industry	No current training package in geophysics but development is being supported by the Mineral Council of Australia. Geophysics course at CIT is highly regarded but under threat due to low student numbers.	Challenging relationship with industry training advisory board.	No relevant current training. Problems being encountered in training package development.

	Cast Metals	**Satellite Systems**	**Sustainable Rice**	**Sustainable Tourism**
Research	High technology tools and equipment.	Satellite communications, tools.	Sustainable development—processes to counter high water usage and groundwater salinity.	Processes, methods and tools for applying principles of sustainable development.
Industry status and development	Mature industry (die-casting) fragmented with many small players using old technologies and few large players using cutting-edge technologies. Growth anticipated due to shift to light metals and to value-adding to raw materials.	No industry yet. Potential for future, but will have high reliance on government funding support.	Rural industry competing in world markets on quality of products. Changes driven by environmental and efficiency concerns.	Tourism is a mature industry that is successful and growing. Sustainable development is being driven by environmental concerns.
Skills demand	Shifting from low skill to technician level as equipment becomes more sophisticated.	Not yet known. Potential for technicians.	Rapid uptake of new products and processes requires upgrade in skills and capacity to deal with changing context.	High levels of demand currently. Application of sustainable development principles will require new skills in all areas of operation.
VET links	Co-operative research centre is seeking to develop stronger links to counter existing lack of VET training facilities.	Centre envisages it will need a strong connection in the future to build a skill base for the new industry.	Through NSW Department of Agriculture has links with agricultural colleges. Centre wants to expand to other VET providers.	Strong link with Tourism Training Australia which is responsible for training package development.
Current VET provision for industry	Industry has poor training record. VET provision very limited as few sites have facilities.	None.	Through agricultural colleges but future expansion.	Substantial but may need to incorporate new approaches.

	Viticulture	Renewable Energy	Photonics
Research	Research seen as the means to an end—new and improved products and more efficient processes.	Systems and tools to create energy from renewable resources.	Tools and equipment for telecommunications, diagnostics and other applications being developed.
Industry status and development	Mature and growing. Success in the global market.	New industry that is growing rapidly now due to government support (e.g. consumer subsidies) improvement of products and environmental concerns and regulations.	Emerging industry. Cluster of companies, many spin-offs from centre. Industry forum established.
Skills demand	Skills upgrades for understanding of new and improved products and processes.	Predicted unmet demand for technicians to install and maintain products.	Anticipated future high level of demand for technicians.
VET links	WINETAC—the industry training council—has responsibility for the centre's education and training program. Good model for others to follow.	Strong link with the Renewable Energy Centre at the Brisbane Institute of TAFE. The centre is seeking registered training organisation status.	With TAFE NSW though the Industry Partnership Centre and developing with Canberra Institute of Technology.
Current VET provision		Growing—particularly through flexible delivery. But training package has imposed limits.	Fee-for-service programs in NSW and development in ACT. Problem with slow training package development.

In all cases, the co-operative research centres are working to produce research outputs of use to industry. For most, this is an established industry, which may be either mature (e.g. cast metals, viticulture) or new (e.g. renewable energy). In the case of satellite systems, no industry has yet been established and in the cases of photonics and landscape evolution and mineral exploration emerging industries are the focus (photonics and 'saltonics'). Where an industry already exists the research is expected to have an impact on the way things are done, and the tools and equipment that are used to do them. Requirements for new or upgraded skills principally arise from the changes that application or implementation of the research outputs will create. In most cases a shift is apparent to higher-level skills through the application of new technologies.

Few of the co-operative research centres have strong links to the VET sector, thus indicating a failure to consider VET as an end-user of the research, or as a mechanism by which information about the research outputs can be disseminated. Three cases offer different models of VET interaction that provide good examples for other centres to follow: photonics, renewable energy and viticulture. In these three cases VET provision is most obviously being developed to accommodate the new skill needs of the industry that are arising from the centres' work.

Overall, the case studies are fairly typical of the co-operative research centres as a whole, with the exception of the three offering good practice models.

High technology companies

The high technology companies studied for the project demonstrate a very limited knowledge of the VET sector and the capabilities of VET personnel. We refer the reader to the study *The undiscovered country: Skills and Australian high technology start-up firms* (http://www.ncver. edu.au). Related to this they tend to have a rather negative view about whether their training needs—which they indicate might be substantial—can be met. This pessimism affects decisions the companies make about expansion, location and investment. It may influence some companies to relocate overseas and thus lead to lost opportunities within Australia. By improving communication with, and therefore knowledge of, the VET sector in these companies, better outcomes may be achievable.

Like the new industries in which they operate, high technology companies go through stages of development which each have different skill needs. VET skills become increasingly important as the companies move from research and development to niche product manufacture to reach a mature stage of mass production.

Companies noted that the qualification demands were not necessarily for new workers. In fact, many noted that they required graduates with both university and VET experience. The preference from companies was not to recruit fresh from the universities or TAFE. Where this had occurred, in most cases, students were undergoing classes to obtain recognition via a qualification of their existing skills.

TAFE/VET qualified jobs created by the start-up companies in the study will number at least 283 by 2002 and the number of university-qualified positions will be 575. Of these, 419 are postgraduate qualifications. The proportion of VET jobs in the cluster was 16% (2000) but will rise to a minimum of 27% (2001) and is in fact likely to be higher by December 2002.

A recent (2000) unpublished survey of 12 broader Australian photonics firms conducted by Tekhne Pty Ltd for the Australian Photonics Co-operative Research Centre predicted 2750 jobs would be created by the 12 firms sampled by 2010, of which 1200 would require VET/TAFE qualifications. This would represent 43.6% of the total employment demand at that time.

The skills that the companies require are also affected by the global marketplace in which the firms operate. Different economic and social conditions, such as the availability of venture capital and military action can alter both the type and number of skills required—and changes can be very rapid. A collapse in investment can cause expansion plans and market entry to be put on hold. Investors might also influence decisions about where the company is to locate—and therefore also about where skills are needed.

Each of the developmental stages the company goes through is marked by a change in the capital status of the company. Capital investment is not always the subject of disclosure but where it is the VET sector would be well advised to see capital injections into start-up companies as a marker for industry expansion and as an indicator for within-company training in areas such as occupational health, safety and welfare, frontline management and project and financial management.

Concluding comments

In this chapter we have presented the main findings synthesised from the extensive data collected throughout this project. In brief, we have indicated that the work of the co-operative research centres produces innovations that can, but won't always, lead to either new or changed skill requirements. There is a role for the VET sector in providing training or re-training to meet these skill needs, but a lack of communication between the sector and the centres inhibits the timely development of appropriate programs and materials and the training of staff to deliver the training required. Where strong links already exist between VET and the centres there are benefits to both sides.

In the following chapters we present in greater detail the material that has led us to these findings.

Chapter 3: Where the journey began … VET and the emerging photonics industry

We began this investigation of the skill needs of emerging industries in Australia with a major question: *Are there other cases in Australia like the photonics industry?*

Based on our pre-existing knowledge and understanding of the Australian photonics industry, we hoped to discover other industries emerging from the research and development of co-operative research centres that:

- would be likely to have a strong demand for VET-trained staff in the near future
- will have skill needs that could be met by VET programs
- might be seeking to obtain VET (especially public-funded VET) appropriate to their skill needs
- could be assisted by VET to become successful.

This chapter tells the story of how and why we came to know something about the emerging photonics industry and its relevance to VET. It tells of the collaboration between the NSW TAFE Industry Partnership Centre (IPC) and the photonics industry that ultimately led to this project. It describes the Australian photonics industry and the ways in which the Industry Partnership Centre has worked with the industry to realise its skill needs and to support and promote a response to them by the VET sector.

What this story does not tell is what more has been learned about the photonics industry and its skill needs in the course of this investigation. This information forms the basis of photonics in the online case studies of this report and of the photonics companies report in *Going boldly into the future: Skills and Australian high technology start-up firms*.

What is photonics?

Photonics is the control, manipulation, transfer and storage of information using photons, which are the fundamental particles of light. It is underpinned by knowledge of the principles of light and builds on and extends understanding and use of electronics, lasers and optical fibres.

Photonics is an *enabling technology*, that is, one having the potential to change the entire basis of competition. Through ongoing research and development many potential uses are emerging of photonics technologies in a variety of fields. Telecommunications is the main focus of the work with a major aim being applications that will meet the heavy demands on bandwidth arising from the use of the internet.

Sensing devices are also being developed for defence and other industrial applications, including equipment for measuring temperature, strain, electric current, vibration, chemical and biological pollution, and sound. Diagnostic equipment for medical uses is also under development.

Photonics competes with other technologies, including new wireless technologies. A 1997 report conducted by the Warren Centre for Advanced Engineering described some advantages of photonics over competing technologies as:

- cheap raw materials

- vast information transmission capacity
- immunity from electromagnetic problems
- relative physical simplicity of photonics solutions
- non-corrosive, non-conducting
- rich variety of sensor techniques.

The Australian photonics industry

The roots of the Australian photonics industry can be traced back to research conducted in the 1960s into the characteristics of optical fibres. However, photonics has only begun to emerge as an industry in its own right in the past few years as commercial products and services arising out of more recent research have started to be created and companies have been set up to take them to market.

While the industry is growing as a whole very quickly, it still lacks critical mass in some sub-component areas. Nevertheless, prospects for the future are good, particularly in telecommunications where photonics technologies will soon replace existing technologies. A pilot study by the Department of Industry, Science and Resources (1999) identified photonics as one of a range of enabling technologies critical to the increased competitiveness of Australian firms over the next few years[2].

Support for research and development from public and private sources has been critical to the development of photonics and thus to the birth of this new industry. Now conducted primarily in the Australian Photonics Co-operative Research Centre, this research was previously conducted by different groups in scattered sites across several universities and enterprises, including the Optical Fibre Technology Centre, at Sydney University, the Optical Sciences Centre at the Australian National University, the Optical Communications Group and Surface Analysis Facility at Royal Melbourne Institute of Technology and the University of New South Wales and the Photonics Research Laboratory at the University of Melbourne. The coming together of these groups to form the co-operative research centre created a critical mass of researchers and gave their work a stronger commercial focus that has accelerated industry development. As at July 2001, the centre has over 100 patents filed.

Although no formal industry association yet exists for photonics, there is a Photonics Industry Forum formed under the auspices of the Australian Electrical and Electronic Manufacturers Association (AEEMA). The forum was launched in 1998 and held the first Australian photonics industry conference in 1999. The forum has a growing number of members, the majority of them small to medium-sized enterprises.

Skill needs

At the outset of this project knowledge of the specific skill needs of the Australian photonics industry was limited, but informed by overseas experience and research and the early stages of some Australian work. The material available discussed skill needs in two ways: needs common to several new technology areas; and needs for photonics in particular.

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[2] The full list were information technology; telecommunications; technologies associated with supply-chain management; pharmaceuticals and biotechnology; chemistry-related technologies; advanced materials (materials science); micro-machinery and nanotechnology; photonics/opto-electronics; smart sensors and machine vision systems; and environment pollution control technologies.

A study of skills required by new technology industries in the United Kingdom (Hendry 1999) examined the advanced materials, biotechnology and opto-electronics (photonics) industries and identified three emerging sets of skills required in different measures and degrees of sophistication by different levels of employees:

- Fundamental understanding of the (specific) materials concerned, with skills in synthesis, design, processing, and fabrication.
- Skills in supporting infrastructure (generic) technologies such as ultra-precise measurement and testing techniques, modelling and simulation.
- Project management skills and skills in concurrent engineering, in which a product is designed in close conjunction with the design of the manufacturing process, and customers and supplier are brought into the process early on in order to meet ever-decreasing product development costs.

In the UK photonics industry Hendry identified needs for a wide range of skills in fundamental science, (e.g. materials science, optics and photonics, software engineering) and for people with a combination of scientific/engineering and business skills. Hendry also noted specialist sub-sectoral needs (e.g. imaging science for displays) and emerging inter-disciplinary skills relating to specialist markets (e.g. biology combined with photonics for biosensors, and chemistry with photonics/optics for pollution monitors). Hendry also referred to needs for high-level craft skills (glass blowing), but found also that many firms need employees with only low levels of skill.

In Australia, the Department of Industry, Science and Resources (1999) noted that enabling technologies such as photonics have a particular need for people with problem-solving ability, communication skills and understanding of the global business environment. They need graduates trained in the traditional 'hard' sciences of physics and chemistry and skilled in management for manufacturing. Lifelong learning was also considered to be important to maintain skill currency.

From the United States Hull and Massa (1998) have indicated that a lack of mathematical and science knowledge among unskilled workers in photonics is a barrier to development of skilled technicians because these skills are necessary for problem solving, including the understanding of what is occurring when a process breaks down. This supports a need for photonics-specific skills at all levels of work.

How many workers will the photonics industry need? Again, information was limited at the outset of this investigation but has since increased. An unpublished survey of 12 photonics enterprises conducted in 1998 for the Department of Industry, Science and Resources by the Warren Centre estimated that if Australian can maintain a market share of 1.2% of the global market by 2010 there will be skill demand for 24 700 workers specific to the industry and 32 000 in associated industries. Twelve firms alone will create 2750 jobs, of which 1200 (44%) will require skills at VET level.

Connecting with VET

Links between the emerging Australian photonics industry and the Australian VET sector were forged between individuals representing four groups all located at the Australian Technology Park in Sydney: Professor Mark Sceats, chief executive officer and Elisabeth Elenius, national communications manager, Australian Photonics Co-operative Research Centre; Rod Galloway, project manager and Angus Robinson, general manager, Warren Centre for Advanced Engineering; Dr Tom Forgan, chief executive officer, Australian Technology Park Sydney Limited, and Karen Whittingham, centre director, TAFE NSW Industry Partnership Centre. This grouping was a unique circumstance which enabled collegial relations between disparate organisations significantly before there was a defined business case for collaboration.

Australian Technology Park

The Australian Technology Park (ATP) was formed in the early 1990s as a result of a joint initiative between the Sydney University, University of NSW and University of Technology Sydney, the objective being to promote research and provide linkages for industry that will enhance future developments for manufacturing and industrial research. The site sets out to achieve these objectives by providing an environment that encourages the growth of innovative technological business and community involvement that focusses on the development of innovation.

One of the goals of the Australian Technology Park was to integrate research and development with education and skills-based training. Dr Tom Forgan, in particular, was integral to providing links between each of the industry-based tenants, research and development organisations and educational bodies in NSW.

NSW TAFE Industry Partnership Centre

The Industry Partnership Centre (IPC) was set up by the NSW government body, TAFE NSW, at the Australian Technology Park in 1998 as a measure to ensure that the VET sector, and particularly TAFE, would be a full participant in the activities, events and developments occurring at the Park. The decision provided an additional dimension to the Australian Technology Park, whose owners and tenants until that time consisted primarily of universities and organisations associated with them.

The centre was established because it was recognised that training support is a key to the competitive advantage of emerging industries in both domestic and global markets. The centre's main objectives are:

- to promote research and linkages for industry that will enhance future developments in manufacturing and emerging technology and information industries
- to provide training solutions for the new technologies that are being developed at the Australian Technology Park.

TAFE NSW's involvement in the development of the Australian Technology Park centres on the requirements for skill recognition and the need to progress from research and development to training and implementation. The Industry Partnership Centre provides technical vocational training and advice to Australian Technology Park tenants and expertise on training standards and policies, training centres and assessments. It collaborates with the Australian Technology Park and its tenants in training, research and development, implementation of programs and projects. It interacts through meetings, conferences and symposia and co-operates in a range of other educational initiatives including student scholarships, and promotions of science and technology. The Industry Partnership Centre is managed by Karen Whittingham, one of the authors of this report.

Warren Centre for Advanced Engineering

The Warren Centre is an independent, industry-linked institute that is part of Sydney University. It is self-funding, relying on donations, bequests, in-kind contributions and support from sponsors and participants in its projects to cover its costs.

The centre's objectives are:

- stimulating innovation in advanced engineering technologies to accelerate Australia's industrial development
- encouraging effective deployment and use of new engineering technologies
- promoting the integration of technology, management, design and enterprise among Australian businesses

- providing independent comment on these issues and their impact on development, national policy, and enterprise.

Members of the centre are drawn from industry, as well as Sydney University.

Australian Photonics Co-operative Research Centre

The centre was established in 1992 and granted funding under the Commonwealth's Co-operative Research Centre program. It was re-funded for a further seven years in 2000. It has four major research programs in:

- *Photonic integrated circuits* – the integration of active and passive optical waveguide devices in planar geometry.
- Novel photonic components – design of new devices.
- Telecommunications technologies – broadband long haul and local access networks.
- Photonic *sensors and signal processing technologies* – test and measurement instruments and signal processing.

The centre has developed a number of 'spin-off' companies for commercialising the products of its research over the past three years . This forms a cluster at the heart of the fledgling Australian photonics industry and a hub, or critical mass, of research expertise in Sydney.

Collaborative activities

Collaboration between the Industry Partnership Centre and the Warren Centre preceded the Industry Partnership Centre's involvement in photonics and was a direct result of the co-location of the two organisations at the Australian Technology Park.

The Industry Partnership Centre worked with the Warren Centre in developing a model to assist Australia's development of emerging industries in the smartcard industry. In 1997 the Warren Centre was granted Commonwealth funding to undertake a *Photonics in Australia* project to determine the value of the potential photonics industry to Australia, impediments faced by the industry and opportunities that should be supported. It would also establish a mechanism for the emerging industry to liaise with government.

The project is discussed in the photonics online case study. Briefly it:

- developed an agreed position on the status of the industry and quantified future prospects with a specific emphasis on the Asia-Pacific Region
- supported the articulation of a clear strategic vision of the future that would help the industry to overcome impediments to its growth
- developed an industry group that would provide a platform to enable government support to be martialled and present a united industry position.

The VET sector was represented in the project team through the TAFE Industry Partnership Centre. Other members included people from industry; university, venture capital organisations and government. In 1998, the team commissioned a benchmarking tour of Australia's photonics capability and findings were distributed and publicised through a seminar at the Australian Technology Park in September 1998 that also launched the Photonics Industry Forum. TAFE NSW became a leading member of the forum and has participated in its development.

Outcomes of the connection

Through the work of the TAFE Industry Partnership Centre in the *Photonics in Australia* project, a strong working relationship developed between it and the Australian Photonics Co-operative

Research Centre. The two organisations cemented this in a memorandum of co-operation (MOC), which in 1998 was developed and signed by the Hon. John Aqualina, then Minister for Education and Training in New South Wales. This was a first for the Co-operative Research Centre program as co-operative research centres are not required in their performance agreements to develop VET links. It was also a first for TAFE, which had not previously had a formal relationship with a centre.

The memorandum of co-operation provided a framework for the development of vocational education and training in the new technology. Its intent was to assist in the transfer of knowledge into the VET sector—which had no products or services in this area. Its rationale was that if knowledge of photonics could be transferred into VET the process of curriculum development could be accelerated and thus a gap would be less likely to develop between the supply of appropriately trained TAFE graduates and the demand for them as jobs were created in the emerging industry.

The centre perceived that the spin-off companies it set up to commercialise its research outputs would need staff with skills and qualifications in photonics and optical fibre technology at the technical, graduate and postgraduate level. TAFE NSW would be able to provide training through the addition of new modules to existing diploma programs and short courses in photonics and optical fibre technology for science and engineering graduates.

Co-operative activities outlined in the memorandum of co-operation included:

- provision of technical and vocational training in Australia or offshore
- provision of training materials, curriculum and training equipment
- development of collaborative training
- joint research and development
- provision of work experience and scholarships or prizes to TAFE students
- other joint ventures.

Through Southern Sydney Institute–Lidcombe College primarily and Western Sydney Institute–Mt Druitt College recently, TAFE NSW has become the major provider of training for the Australian photonics industry. A course of 10 modules has been developed with assistance from staff of the co-operative research centre and is available on a fee-for-service basis. The take-up of these modules by the centre itself and also by its participating organisations has been quite high. The modules are:

- Photonics Industry Overview
- Introduction to Photonics and Devices
- Photonics and Devices and Applications 1
- Introduction to Optical Communications
- Optical Fibre Transmission
- Photonics and Devices and Applications 2
- Optical Communications and Networks Theory
- Photonics Analysis and Design Principles
- Wavelength Division Multiplexing Devices
- Wavelength Division Multiplexing Networks

As a consequence of its early involvement with and contributions to the development of the photonics industry TAFE NSW has been able to acquire equipment and supplies at substantially reduced rates or through in-kind support. Thus Lidcombe College now has the only VET-based photonics laboratory in the country. Additionally, linking with the centre has provided opportunities for staff to upgrade their professional skills. In 1997 and 1998 the centre hosted Michael Moulten, teacher of Lidcombe College who then prepared the 10 short courses or modules for delivery which is on a fee-for-service basis. In February 2000 the centre hosted Doug Fraser of Mt Druitt College, who subsequently prepared a new photonics course for offering in the second semester of 2000 at that college. A fully accredited diploma in photonics has been registered in NSW for implementation in 2002 by TAFE NSW.

Developing national VET programs

The Industry Partnership Centre has encouraged the co-operative research centre to take action to achieve publicly-funded support for training in the photonics industry. The Industry Partnership Centre has introduced the co-operative research centre to the structures and mechanisms of the VET sector, networked the centre to main VET stakeholders, discussed the industry's skill needs with senior politicians, VET bureaucrats and managers and lobbied for funding. However, much remains to be done for there are no relevant competencies in the relevant training package.

Structural impediments exist which inhibit the responsiveness of the national system. In particular, the present system for the development of training packages is, according to the co-operative research centre, 'unresponsive, unwieldy and dense'. Training package development is dependent upon conditions that have not existed in the photonics industry. For instance, it requires:

- the existence of companies so that competencies can be determined from underpinning technology knowledge, company processes and production methods
- an industry training advisory board aware that a new industry cluster is forming
- an industry able to articulate its needs to the industry training advisory board
- registered training organisations with the capabilities to deliver appropriate training.

To date many attempts have been made to include photonics in the telecommunications training package but have failed since there had not been a review of the package since its implementation in 1997.

In these circumstances, both Lidcombe College and Mt Druitt College are using their discretion to increase skills and awareness of photonics in existing telecommunications students. TAFE NSW Telecommunications and Electrical Engineering Diploma students are undertaking photonics-based research projects where there are opportunities in their existing courses. However, this effort will not be enough to meet future skill needs. The Photonics Co-operative Research Centre is located across three states and the industry is growing in five (predominantly in NSW but substantially in the ACT and Victoria) This makes it imperative that VET develop a photonics capability outside NSW.

Recently effort has begun to facilitate the entry of Canberra Institute of TAFE into the co-operative research centre. Lidcombe College has hosted staff from Canberra Institute of Technology and assisted them in the development of relationships with the centre and its spin-off companies. With a view to raising interest in photonics by the VET sector a number of TAFE NSW/co-operative research centre awareness-raising activities have been undertaken. For example:

- In Victoria, Mark Sceats, chief executive officer, Australian Photonics Co-operative Research Centre and Karen Whittingham, director, TAFE Industry Partnership Centre, addressed around 90 delegates who were board members and senior management from each of the Victorian TAFE institutes as well as industry training advisory boards at the annual conference of the Victorian TAFE Association in 2000.
- The TAFE Industry Partnership Centre in collaboration with the co-operative research centre hosts school student visits to the Australian Technology Park and all visiting students are briefed on the nature of photonics. Over 3000 students attended this program in 2000 alone.

Summary and some observations

Links between the Co-operative Research Centre for Australian Photonics and TAFE NSW developed through the co-location of the two organisations at the Australian Technology Park and their participation in a project investigating the future of the industry. The links have culminated in a memorandum of co-operation.

Through its links with the TAFE Industry Partnership Centre the co-operative research centre has gained:

- a deeper knowledge of the VET sector
- access to appropriate training for its spin-off companies
- a partner able to assist with many of its activities, particularly the dissemination of knowledge of the industry and its needs and opportunities.

TAFE NSW has gained:

- access to expertise in photonics that has enabled it to develop a capability in the area
- opportunities for professional development for staff
- early knowledge of an emerging industry that will have substantial training needs in the future and thus first mover advantages
- support to establish the first VET-based photonics laboratory in Australia.

The emerging photonics industry has gained:

- acceleration of the development of a course that will help to fill a skills gap
- access to assistance with the difficult negotiations required to obtain funding for VET training
- some confidence that its future training needs will be met
- to some extent, a sure footing of the skills base for the industry.

Chapter 4: A briefing for the journey—predictions and trends in skill requirements

Why should we predict skill needs? How can we make predictions? What is known already about skill needs and the ways in which they are changing?

In this chapter we draw on the extensive literature collected for this project to discuss these questions, informed by some of the findings of our research. Firstly, we explore whether or not there is a need to predict skill needs, then identify some difficulties in making predictions—particularly for emerging and new industries—and we note some methods being used and their results. We identify general trends in skill needs across industries and work being done to assess the skill needs of emerging and new industries. The major forces driving changes in skills are also noted. Finally we discuss some relevant issues for vocational education and training.

Predicting skill needs: Why and how

Why predict skill needs?

Matching the supply of skills with the potential future demand is critical to ensuring continuing economic growth and maintaining competitiveness. As Horn (1997) states:

> If we can accurately forecast future skills requirements, we will have a key success factor for continued growth. (p.2)

Without information about future skill needs, individuals might under-invest in their own skill development, employers may under-invest in training their workers and planning for VET may neglect new skill needs, particularly in new and emerging industries. Skill forecasts can guide decision-making to avoid the adverse consequences of skills shortages. Skill shortages can lower productivity, for instance, if a firm has to place unskilled workers in skilled positions. They can inhibit the introduction and successful implementation of new technology. They can give skilled workers a bargaining position that enables them to negotiate inefficient working conditions and can cause the wages of skilled workers to rise relative to the unskilled. As competition for scarce skilled labour drives wages upward, a surplus of unskilled workers can create downward pressures on the pay of these workers. Skill shortages are also among a range of factors that can reduce the quality of products and services (Haskell & Holt 1999).

In the long term, skill shortages can contribute to the development of a low skills and low wage equilibrium as enterprises adapt and change their skill demands accordingly, installing technology and choosing product mixes requiring relatively lower degrees of skill intensity. The economy can become stuck in a 'low skills trap' (Finegold & Soskice 1988) from which escape may be difficult—a vicious circle of low productivity, low training and a small number of skilled jobs[3] (Haskell & Holt 1999). On the other hand, a healthy supply of skills can promote the adoption of new technologies and systems in mature industries, and contribute to increases in productivity and efficiency.

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[3] Curtin *(Is Australia locked into a low skills/low quality cycle?* Centre for the Economics of Education and Training working paper no.10, October 1996) addresses the question of whether Australia is stuck in this sort of a trap and for a number of reasons concludes that it is. He indicates that many enterprises in Australia fail to take a long-term, strategic approaching to human resources planning and development. Unions are caught in a short-term cycle of attempting to bid up wages; individuals seek to lift their return to skill by moving between employers and governments are more concerned with training the unemployed in narrow and specific work skills to gain access to entry-level jobs.

In trying to avoid skills shortages, is there a risk of an over-supply of skills? Horn (1997) warns that the disadvantages of skills under-production outweigh the disadvantages of skills over-production. Providing skilled people will give a major competitive advantage and ensure there is little supply pressure leading to increased wage costs. At worst, over-supply can lead to some relocation of skilled workers into other sectors and possibly renewed emigration.

Methods and approaches

Many different methods are used to forecast skill needs. They vary in focus and results and draw on a variety of sources and types of data. All these methods have limitations which mean that their results must be used carefully. A strong theme in the literature, and in the consultations we conducted for this project, was that there is a need to improve forecasting methods.

Haskell and Holt (1999) note that forecasters tend not to look directly at skill needs because they need to know about the past in order to form a view of the future and there is little consistent quantitative information available about past skill patterns. Thus most forecasting work centres on occupations.

Occupational forecasts can provide some information about the balance between the need for skilled and unskilled workers but more information may be required. In addition, occupational change may not always be a good proxy for skill change. Some occupations consist of one specific task, others of multiple tasks. Where each task requires a certain skill, mapping tasks into occupations and then into skills is relatively straightforward in principle, but over time the bundle of skills used in the tasks that together comprise an occupation may change—with fewer lower-level skills and more high-level skills being required (or vice versa). In this way, occupational classification systems gradually become out of date.

Although this problem can be dealt with reasonably by periodical re-classification of occupations, a more difficult problem can occur where over time the relationship between tasks and occupations, and hence skills, becomes blurred. Technical change may be one cause. In some cases the rise of multi-skilling can make occupational tracking and forecasting inappropriate for assessing skill needs.

Drawing on industry examples Haskel and Holt identify that in many occupations vocational skills are fading in importance relative to multi-skills and that where this is particularly pronounced an occupation can cease to be a distinct category. This is not a profound problem for skills forecasters where it happens in specific ways and two occupations meld into one, but if many different occupations were to blur into each other it would become more difficult. A further problem they identify with the use of occupational forecasts as a proxy for skills is that the results can provide misleading information about skill needs where an occupation is in numerical decline, but the skills required in the occupation are rising. For instance, they indicate that in the United Kingdom the number of engineering technicians is falling, but the skill levels of those remaining in the occupation are rising.

Haskel and Holt conclude that in 'practical reality' we have to be satisfied with forecasting methods that are known to be less than perfect but which are nonetheless helpful. Changing occupational patterns say something, but not everything, about changing skill needs.

Recognising the limitations of forecasting methods, some approaches to forecasting now combine statistical information with data drawn from a variety of other sources. Haskel and Holt suggest mapping the current relationship between skills and occupations, and information on how employers expect skill needs by occupation to change, to forecasts of occupational change. Another method they recommend is to use case study evidence to supplement and inform occupational and skills forecasting.

International forecasting initiatives provide some examples of the use of a combination of data sources:

- In Ireland the government has established a business education and training partnership to develop national strategies to tackle the issue of skill needs, manpower forecasting, and education and training for business. The partnership includes an Expert Group on Future Skills Needs, which has attempted to identify the skill needs of different sectors, advise on the actions needed to address them, and to develop forecasting techniques to assist in anticipating future skill needs The group has undertaken a general examination of the demand for and supply of skills at a macro level in the economy and has assessed in more detail skill needs in electronics, information technology and engineering. Its approach uses a medium-term macro-economic model as a base for economy-wide projections, but recognising that accelerating change is not fully accounted for in this model replaces projections for some rapidly changing industries (e.g. information technology) with detailed job growth projections from sectoral studies (Horn 1997).
- In Finland two different forecasting methods are in use. The first aims to anticipate demand for vocational education and training and involves the National Board of Education in collecting and analysing data from a variety of sources to create scenarios with differing views on the future of changes in working life and labour demand. The base data is drawn from forecasting institutions; research and literature, the social partners in the research project, training committees, authorities responsible for regional development and education managers. The scenarios are analysed by experts and by interest groups. A model is derived and tested against statistical information and by experts and interest groups. Results indicate demand for new labour by occupational group; intake needs by field of study and level of education; and educational qualifications (National Board of Education, Finland 1998).

  The second method is used to analyse occupational change. It uses description and measurement of the actual activities that workers in certain occupations perform to derive an overview of many occupations within a job family, rather than a description of a single occupation. It uses concrete activities in job descriptions; clustering of job activities on the basis of quantitative data; data forecasting changes in job content and involves social partners in the preparation and interpretation of the analysis (National Board of Education, Finland 1998).
- In several Organisation for Economic Co-operation and Development nations cluster analysis has been applied successfully to examine policy aimed at fostering innovation. It samples the network of users of a new technology and the knowledge and skill needs they will have when applying the technology in their particular context (Roelandt & Hertog, 1998)[4].

In the case of emerging and new industries, the lack of historical information about occupations and, therefore, skills is a particular problem in predicting future skill needs. However, if investigation can uncover whether the industries employ (or expect to employ) workers in traditional occupations, occupational forecasting may be useful, especially if it is combined with information about the industry itself, such as its structure, its customers and its markets.

Many factors can affect the growth and success of a new industry and thus need to be considered in assessing skill needs. They are particularly important in any assessment of the scale of skill needs because an emerging or new industry that grows only slowly, or fails, will have little to no demand for workers. The factors, which are highlighted in the literature, and which also are clearly evident in our case studies are:

- the social, political and economic environment

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[4] Roelandt and Hertog note that successful and innovative firms tend to be linked in clusters that can be characterised as networks of strongly interdependent firms (including specialised suppliers), knowledge producing agents (universities, research institutes, engineering companies), bridging institutions (brokers, consultants) and customers. In each of these networks innovation and economic growth occur within a unique combination of organisations tied by knowledge and production flows. Incentives for the participants to come together in clusters include to lower transaction costs, to develop new skills, to overcome (or create) entry barriers in markets and to speed up the learning process.

- regulatory regimes
- access to financial capital
- competition
- speed to market
- government support
- consumer perceptions
- supply of required skills
- research and development support.

Government support has been critical, for instance, to growth in the environmental industry, an area in which several of the case study co-operative research centres are working. It has provided useful information about the potential market, provided some capital funding, subsidised costs to promote consumer demand, created a supporting regulatory regime and also drawn attention to the need for training.

Hendry (1999) considers some of these factors in an examination of the skill needs of three new technology industries in the United Kingdom: advanced materials, biotechnology, and opto-electronics (photonics). He identifies that these three industries combine advanced engineering techniques, fundamental science and a fusion of sciences and that this combination has enormous implications for skills. For each of the industries he assesses skill needs by analysing information in five steps, outlined in table 4.1 below.

Table 4.1: Steps in assessing the skill needs of new technology industries

Step	Activities
1 Sector profile	Identification of the characteristics of the field, including the nature of the new technologies.
2 Growth prospects	Identifying commercialisation prospects and progress, market size and growth, contribution to added value and performance in other fields, etc.
3 Key skills	Identifying the major skill sets required for manipulating the technology, for applying the technology, and for management in the field.
4 Skill needs, gaps, shortages, utilisation	Collecting any information that is available about skill gaps and shortages. Examining recruitment sources and the provision of education and training.
5 Summary	The major points that arise from consideration of the work in steps 1–4.

Source: Adapted from Hendry 1999

Industry training advisory boards in Australia may use similar models in their analyses of existing industries but in the case of a new industry, which has no industry training advisory board, this approach could be particularly useful to establish initial skill needs information. This type of approach was used by the New South Wales TAFE Industry Partnership Centre in 1997–98 to determine the viability of the participation of the NSW TAFE Commission in new industry areas.

Skill need predictions

General trends in skill needs

Two general trends are identified in requirements for skills in Australia and other industrial nations: a growing demand for higher-level skills and an increasing emphasis on generic skills and attributes.

These trends appear to be occurring across most industries and further emphasis on these types of skills is predicted for the future.

The generic skills that are being increasingly sought are both 'hard', such as information technology skills, and 'soft' such as problem-solving skills, team skills, and ability to adapt. An information technology capability is becoming required alongside basic skills such as literacy and numeracy and inter-personal or relationship skills, communication and teamwork skills. A stronger focus is developing on attributes such as a capacity to learn and a willingness to embrace change. The ability to participate in self-managed work teams and multi-skilling is increasingly highly valued. Management skills are being sought, not only in the production 'front line' but also in sales, service, and financial management. (Allen Consulting Group 1998; Giddens & Stasz 1999; Stasz & Brewer 1999).

Employment growth is generally expected to favour skilled over unskilled workers, although a mix of general and specific skills and personal attributes is becoming increasingly important (Department of Employment, Education and Training 1995; Adams & Meagher n.d; Allen Consulting Group 1998).

In Australia there has been a 'stagnation and decline' since 1985–86 in employment in the occupational category routine production workers, which includes many unskilled occupations. Employment growth has occurred principally in in-person service occupations at the lowest skill end of the employment spectrum—and mostly in casualised form. Female employment has consistently outgrown that of males, with women responding faster to a growing demand for conceptual symbolic analysts. (Maglen & Shah 1999)

Stuart and Dahm (1999) identify four types of skills that will be required in 21st century employment:

Basic skills	Basic skills in reading, writing, and computation are needed in jobs of all kinds. Reading skills are essential as most employees increasingly work with information––on computer terminals, forms, charts, instructions, manuals, and other information displays. Computation skills are needed to organise data for analysis and problem solving. Writing is an essential part of communications, conveying guidance to others, and in establishing a permanent base of information.
Technical skills	Computer skills are becoming baseline requirements for many jobs. Workers use a growing array of advanced information, telecommunications, and manufacturing technologies, as employers turn to technology to boost productivity and efficiency, and to deliver services to customers in new ways.
Organisational skills	New systems of management and organisation, as well as employee–customer interactions, require a portfolio of skills in addition to academic and technical skills. These include communication skills, analytical skills, problem-solving and creative thinking, interpersonal skills, the ability to negotiate and influence, and self-management.
Company-specific skills	New technology, market changes and competition drive companies to innovate, constantly upgrade products and services, and focus on continuous improvement of work processes. As a result, employees must frequently acquire new knowledge and skills specifically relevant to the company's products and services, and their production processes or service delivery modes.

(adapted from Stuart and Dahm 1999)

Judy and D'Amico (1997) predict that future prospects for unskilled workers will be poor. Low-skilled jobs will disappear or be available only at depressed wages. Automation will continue to displace low-skilled or unskilled workers and in a global labour market low-skilled or unskilled workers will have to compete for jobs and wages locally and around the world. Three worlds may emerge by 2020. The first may comprise a relatively small elite of highly skilled workers who are the designers and manipulators of the most advanced ideas and technology and command high incomes. The second world, which may coexist uneasily with the first, will consist of low income workers. Some, particularly in manufacturing will be subject to the vagaries of economic cycles and to variations in wage levels in other countries. Others may exist in an upper and rather narrow spectrum where jobs respond to local demand for services. They may be able to earn a reasonable living in some localities. The third world will comprise people from the two other worlds who are permanently idle.

In his examination of emerging technology industries in the United Kingdom, Hendry (1999) identified that skill needs differ according to the industry's stage of development. He visualised two main stages, which are shown in table 4.2, below:

Table 4.2: Stages of development in a new technology industry

Stage	Characteristics	Skills and training
Developmental stage	Fundamental properties of the new technology are being worked out. Firms making the basic materials which form the building blocks for end products need to master new techniques.	Scientists have to work across disciplines. Implications for higher education systems and the cross-disciplinarity of courses.
Application stage	The basic science and technology become established and companies start to solve the technical problems of making things.	People are needed who can work within the new technology and apply established production technologies and disciplines in fabrication and assembly. This requires a gradation of skills from clean-room operations to project management and process control.

Source: adapted from Hendry 1999

As we noted in chapter 2, not all new industries are based on new technologies, and thus it may not be possible to generalise Hendry's schema to all types of new industries. However, the material we have collected in this study supports the view that skill needs change as an industry matures. For instance:

- In the case of photonics (emerging industry): over the long period in which the technology has been developed, the greatest need has been for research skills. As the technology is becoming embodied in products, and these products are moving to the market, a greater emphasis is being placed on management skills. To produce, maintain and service these products, new forecasts are pointing to increasing demand for lower-level and technical skills.
- In the case of renewable energy (new industry), products have been on the market for some time and demand for these products is rising as the quality of the products increases and the cost falls, in part due to government subsidies. Technicians are increasingly being sought who have an understanding of the technology and an ability to install, maintain and service these products.
- In the case of mining technology and equipment (mature industry), research led to the development of new equipment to address existing process efficiencies. When this equipment was retro-fitted to existing underground mining equipment to provide self-guidance a need for re-training and skill/upgrading of existing operators emerged[5].

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[5] In this case, lack of links between the CRC and VET led to a significant time lag between development and application of the technology and development of the competencies to address the training demands by the Mechanical Engineering and Related Services Industry Training Advisory Board.

However, our case studies and surveys of the co-operative research centres suggest a slightly modified version of Hendry's model, with three phases rather than two in the development of an industry, each with different skill needs:

- *A developmental stage* in which ideas/technologies are still being worked out and in which the primary need is for research and research management skills (e.g. satellite systems).
- *An intermediate stage* in which planning takes place for taking new products and services to market, setting up and managing new companies and clusters of companies. Skill needs are therefore primarily in commercialisation and related areas and in business management (e.g. photonics).
- *A mature stage* in which business and management skills remain important and research skills are useful for further development, but there is an increasing emphasis on lower-level and technical skills to support the manufacture, installation and maintenance of products and the provision of services (e.g. renewable energy).

In Australia, the Department of Industry, Science and Resources investigated the skill needs of emerging industries in a survey of co-operative research centres, conducted in 1999 (DISR 2000). The survey asked the co-operative research centres to identify:

- industries likely to emerge in their sectors over the next five to ten years
- workforce skills that will be needed to support these industries.

As we discuss in chapter 4, the majority of co-operative research centres are aligned with, or working within, mature industries and their focus is on process and product improvements to increase efficiency and quality in these industries. However, in this survey many were able, perhaps optimistically, to point to some new industries that might arise. The opportunities identified were many and varied. Consistently however, the centres described them as niche opportunities for new companies, rather than whole new industries.

As few centres in the Department of Industry, Science and Resources study identified a need for skills below first degree level but greater demand for skills at the postgraduate level (i.e. to support research and development). It appears that much of the foundational work required for the development of these industries is now only in the first of the three stages identified above. That is, in most cases, the fundamentals, such as the properties of technologies, are still being worked out. However, the survey also found that the centres expect managerial and administrative skills to be in high demand across all industries, and believe that a blending of technical skills with commercialisation and business planning skills will be particularly important. This suggests that the centres are looking forward to the period in the future when the second of the stages identified above is reached, when new industries will be formed and plans formulated to manufacture and market new products.

Hendry's examination (Hendry 1999) of three new technology industries in the United Kingdom clearly shows that skills gaps are emerging at the technical level as these industries move toward maturity. In opto-electronics (photonics) for instance, he identifies that these skill gaps are creating difficulties for firms and limiting growth. Hendry also identifies other dilemmas facing new industries: to what extent will workers require industry-specific skills? Will skills be transferable from other industries? Will workers be able to meet the needs of these industries with 'soft' skills, such as analytical and communication skills, or will they require a particular understanding of the new technology and its properties? An important factor in considering these questions identified by Hendry is that some new skills make existing skills redundant and thus are 'competency-destroying'.

Advanced materials

There is a strong science-base and a well-developed infrastructure to serve higher-level skills. There is a well-recognised need for cross-disciplinary knowledge and skills but there have been difficulties in establishing the right balance in undergraduate education between generic and material-specific knowledge. Project management and collaborative skills to work with customers, suppliers and the research infrastructure are important, but there is a weakness in advanced materials industries in this area (particularly in polymers), especially in certificated technician training.

Biotechnology

This is a fast growing sector in the United Kingdom on account of a strong science base and relatively large population of new young firms. It is at an early stage of development and is as yet negligible in overall employment terms, but this will change as successful products come through the lengthy cycle of product development. Management is a critical skill, although the industry is able to draw on a number of sources for experienced people from pioneering first generation companies and through its symbiotic relationship with large pharmaceutical firms. As the industry grows and new products get closer to production, skill shortages are likely to become more pressing in areas such as biochemical engineering, which reflects the fundamental challenge of 'technology fusion'. Biotechnology is a 'competence-destroying' technology and is likely to have impacts on skills and employment in pharmaceutical and chemicals.

Opto-electronics (photonics)

This is a large but very diverse sector with enormous growth prospects, which employs a wide range of skills. Firms complain of quite serious shortages of technical skills, which restrict their development. There is a particular shortage of people who combine technological knowledge with business skills. In-house development of skills has been a particular feature of the industry and as firms continue to grow and change by responding to the market there will continue to be a premium on experience and learning developed inside the firm. The clustering of the industry makes it feasible to identify skill needs regionally, although the market for higher-level skills is national (and international).

An important conclusion of Hendry's work is that these three new technology areas suffer because they are enabling technologies and so will underpin developments in other major industries. As such Hendry believes that they will require a 'champion' if they are to attract people to learn relevant skills. He notes that problems arise primarily in a lack of management and commercial skills to complement technological training. This differs according to the stage of development of the industry, but all three industries experience it to some respect.

Hendry's findings are a warning to Australia's emerging industries and the education and training sectors that skill needs must be investigated comprehensively and skill gaps addressed quickly if new industries are to be successful. If the industries he investigates cannot acquire the skills to overcome the shortages, their future is not assured.

Drivers of changes in skill needs

Two major drivers of change in occupations and skills identified in the literature are globalisation and technological change. These factors work together, as well as separately, to make new demands on industries and workers. A third factor noted in the literature is the emergence of the political consumer and new demands on governments and industries for clean, green environmentally friendly products and the adoption of sustainable practices in existing and new industries. As our study shows, the environmental movement has a strong impact in the Co-operative Research Centre program.

Through globalisation and the technological change that has hastened its pace, some traditional industries are declining, while others are growing. Occupations are changing as work is being re-organised, new technology is being introduced and team-work is becoming more widespread. Enterprises and workers increasingly are expanding traditional frameworks to embrace the needs of customers in other parts of the world. A tendency toward the fragmentation of production (Maglen & Shah 1999) means that labour markets operate across traditional boundaries. Consequently, workers trained in one locality may gain employment in another. Technological literacy is increasingly required of workers to endow competitive advantage.

Facing global competition, industry is focussing on the key skills required for the productivity of the enterprise and is restructuring its workforce in order to maximise use of skills (Allen Consulting Group 1998). Employment trends show growth in part-time, temporary and contract work, an increase in telecommuting, or working at non-traditional work sites such as satellite offices, wider adoption of self-led teams and use of temporary, cross-functional, multi-disciplinary teams with globally and ethnically diverse memberships (Boyett & Boyett 1998).

New technologies are fuelling the growth of 'knowledge work' (Brown 1999). As they take on more of the routine tasks performed in the workplace they create a space for workers to address the more complex tasks that require thinking, understanding, assimilating new knowledge, and problem solving. Workers experience increased pressure to develop the new skills that will enable them to participate in the knowledge revolution (Halal 1998).

Knowledge workers 'think, work with ideas, and make decisions' (Shea 1998). They analyse, synthesise, and evaluate information and use it to solve many different problems. They are likely to be highly educated, creative, computer literate, and have portable skills that make it possible for them to move anywhere their intelligence, talent, and services are needed (Munk 1998). Their main value to an organisation is their ability to gather and analyse information and make decisions that will benefit the company. They are able to work collaboratively with and learn from each other. They are also willing to take risks, expecting to learn from their mistakes. Knowledge workers are continually learning, aware that knowledge has a limited shelf life (Miller 1998).

Consumers in Australia and other western nations are showing a growing preference for products and services produced and delivered in a sustainable fashion—even if this means paying a higher price. Consequently there is an expanding market for 'green' products. 'Greenness' is being used as a marketing tool and investors are favouring enterprises that operate in a socially responsible manner, seeking out 'ethical investments' that meet 'green' principles.

The growth of 'green' industries has accelerated and strengthened as governments have adopted many domestic and international regulations, standards, treaties and agreements to protect the environment. Most states and territories in Australia have Environmental Protection Acts (or their equivalent) and Australia is a signatory to several international agreements, for example, to control pollution through the reduction of greenhouse gas emissions.

Enterprises and industries are responding to the environmental movement by re-inventing themselves as good corporate citizens, aware of and responsive to the needs of the societies and environments in which they operate. Existing industries are changing the ways in which they operate so that they can meet their obligations under environmental laws and agreements while also seeking to gain by providing some new 'green' products and services and adopting sustainable practices. Whole new industries are also developing based on the products and services that enterprises and communities need to help them meet their legal obligations and new standards (Astolfi et al. 2000). The development of these green industries has been a gradual process since the 1970s but has gained pace in recent years in the context of international concerns about global warming and growing environmental awareness and concern among communities, consumers, enterprises and industries.

The importance of environmental drivers is evident in that of the 67 co-operative research centres (including expired centres) studied in this project, six have the word 'sustainable' in their titles:

- sustainable production forestry
- sustainable rice production
- sustainable sugar production
- sustainable tourism
- sustainable cotton production
- ecologically sustainable development of the Great Barrier Reef

Overall, about a third (23), have environmental objectives, including the 14 co-operative research centres in the specific 'environment' industry category, five in agriculture and rural-based manufacturing and four in mining and energy.

The application of the principles of sustainable development creates a number of skill needs because it entails a substantial shift from the past. For instance, in the case of sustainable tourism, moving the industry to a more sustainable footing requires workers to have knowledge of the principles of not only sustainable development, but also environmental management, environmentally sensitive design and methods for assessing social and environmental, as well as economic, performance. Adopting 'sustainability' requires also that resources are used differently—and draws on different types of resources. These changes pose a challenge, particularly for workers whose knowledge and experience are based on a different set of principles.

Discussion: Issues for vocational education and training

Predicting skill needs

Although skill-forecasting methods are acknowledged to be less than ideal, there is still a strong case for predicting skill needs. Moreover, forecasts can be improved by using methods which combine data from several different types of material, such as quantitative data and case study reports.

There is a strong case for acting on skill predictions. An adequate supply of required skills is strongly indicated as contributing to the success of emerging and new industries—as well as mature industries. The difficulties faced, for instance, by the opto-electronics industry in the United Kingdom due to a lack of skills, may be replicated in the Australian photonics industry if training is not provided to meet the skill needs that have already been forecast (see chapter 2 and photonics case study).

This raises dilemmas for the Australian VET sector. What action should be taken in response to general changes in skill needs and to particular forecasts of skill needs, such as for new or emerging industries? Given that many factors will affect the success of an emerging or new industry, would it be best to wait until its future appears secure before investing resources in providing training for such an industry? At what stage should planning begin for training for emerging and new industries?

In the context of general changes in skill needs, continual learning throughout life (lifelong learning) is identified in much of the literature as necessary to enable workers to adapt and extend their existing skills and develop the new skills required in their work. Lifelong learning has also been recognised as requiring both quantitative and qualitative changes in VET—and in raising some difficult funding issues, such as who will pay for the extra training?

Flexibility to meet new needs as they arise is also identified as a key element in the education and training response to change. As well as a way of addressing demands for 'just-in-time' or niche training, it is also seen as a way of partly addressing the problem of 'time lag', that is, the time required to develop and deliver new curricula and programs and produce skilled workers once a need for skills has been identified. The Department of Industry, Science and Resources (1999) identifies that this time lag can be five years or more if employers have to wait for a new course or program to be set up and graduates to complete it, though it may be less if existing workers are able to learn new skills and apply them immediately on-the-job.

In VET the time can be considerable between the identification of a new skill requirement, framing a new competency, and including the competency in a training package. In part, the length of this period is due to the length of time between formal reviews of training packages. Because of the time lag, both new and mature industries suffer frustrating limitations from an inadequate supply of skilled labour. State-based VET initiatives may alleviate some of this pressure but do not overcome it. The problem can be particularly pronounced if the employers or new companies do not see the benefit of early involvement of training organisations in the developing industry or employers are unable, or unwilling, to pay for customised fee-for-service training for their workers, offered outside publicly-funded programs.

The Department of Industry, Science and Resources suggests that to overcome the time-lag problem governments should target support for emerging *capabilities* such as policies and programs that encourage development of characteristics and competence in individuals and organisations that will deliver competitive advantage (DISR 1999). This has merit, but may be less effective where an emerging or new industry requires workers with a particular understanding of a specific new concept or technology.

In considering when the VET system should respond to forecasts of skill needs of new ideas, an important factor is that formal education and training have a stronger role in some stages of industry development than others. Hendry (1999) suggests that in the early stages of an industry formal education and training systems will have only a minimal role as most skill needs will be able to be met through in-house or informal training:

> During the phase when the new hybrid skills are being formed, … skill development will rely particularly on in-company development to convert people from the pure disciplines they are likely to have been educated and trained in.

This role will strengthen, however, as the industry advances to later stages of development:

> As the technology and methodologies become established, this [in-company development] may be externalised into the education and training system. (Hendry, p.3)

Our investigation found that if only a few workers are required to have new skills, the co-operative research centres may fulfil these needs through the industry seminars and workshops in their education and training program. However, when numbers increase beyond the capacity of the centre, the industry may look to educational institutions and systems to take on some of this work.

Of the three stages in the development of an industry, (developmental, intermediate, mature) noted earlier, formal vocational education and training will be needed most in the third stage, when a new industry is competing in the market and skills are required to support the manufacture, installation and maintenance of goods and services. However, developing appropriate training courses and materials, and negotiating the inclusion of new competences within training packages can take considerable time, so planning to deliver VET should start before this stage begins—perhaps in the intermediate stage when commercialisation options are being worked out. In our view this would be earlier than most planning of this type occurs now.

Overseas responses

Overseas, there is evidence of concerted and active responses to new skill needs, such as the work of the Skills Task Force in the United Kingdom (www.dfee.gov.uk/skillsforce), and of the emerging and evolving occupations project in Texas. In contrast, the Australian literature shows limited systematic action to plan for, or put in train, specific changes in education and training for new skill needs, especially in emerging and new industries. While the rhetoric is considerable, the documents examined point to small pockets of activity in disparate locations rather than sustained and substantial action throughout the nation.

The United Kingdom government has formed a national taskforce, charged with providing advice on the nature, extent and pattern of skill needs and shortages (together with recruitment difficulties), how these are likely to change in the future and what can be done to ease such problems. The taskforce has commissioned research, held consultations, invited submissions and set up an expert group in labour market studies (www.dfee.gov.uk/skillsforce). In the United States the State of Texas has set up a project to identify target industries with the best possibility for employing emerging and evolving occupations. The aim of the project is to give up-to-date occupational information to decision-makers in the Texas employment and training system. The project overview states:

> By basing workforce curriculum on labour market data and employer input, educators and trainers are able to align instruction according to actual skills in demand. Once these skills are acquired, students entering the workforce, workers contemplating a career change and dislocated workers seeking re-entry into the labour force will develop career resiliency—a vital asset in our rapidly changing global economy. (www.soicc.state.tx.us/emerging/overview.htm)

The project has collected information about emerging occupations and this is published on-line, listing different occupations, their requisite knowledge skills and abilities, minimum education and training requirements, wage estimates and projected employment opportunities. The project is also investigating the level of knowledge, skills and abilities workers need to perform well in these occupations. Education and training institutions throughout the state are being contacted to learn how they are updating curriculum with respect to the skill requirements of the listed occupations.

Table 4.3 below presents an example of an occupation listing from the project's web-site for the 'emerging occupation' of electronic research technician. This particular occupation might be found in both mature and new industries and is a good example of one requiring a combination of technical and general skills.

The Australian VET system is under considerable pressure in the fast-growing knowledge-based economy due to many changes it brings to work and work skills. The Department of Industry, Science and Resources (1999a) suggests that the VET system should develop a capability to forecast and respond to changing demand and to strengthen its partnerships with industry. (It also suggests that universities and schools should become more integrated with the VET system and more responsive to the needs of industry.)

Participating more pro-actively in the national innovation system could be one way in which VET organisations could take up the Department of Industry, Science and Resource's challenge. It would be an effective way of gaining first-hand high quality information about research and development, its possible influence on skill needs, and about the state of new industries. This would prove useful in planning for the future.

Table 4.3: Texas emerging and evolving occupations project

Electronic research technician — **Emerging occupation**

Electronic research technicians search for and retrieve information from the internet and other electronic databases. They select which websites, electronic bulletin boards, search engines, and keywords to use to achieve appropriate results. They clip the text and data that are pertinent to the inquiry. Some technicians also analyse the information and write abstracts, summaries, or reports. These technicians may specialise in a particular subject matter or respond to all types of inquiries.

Knowledge	Skills	Abilities
Computers and electronics	Active learning	Oral comprehension
English language	Information gathering	Written comprehension
Customer and personal service	Information organisation	Fluency of ideas
	Reading comprehension	Inductive reasoning
	Writing	Deductive reasoning
	Time management	

Education and training requirements – To gain knowledge in a wide variety of topics, persons interested in this career should pursue an Associate Degree in Liberal Arts and Sciences. Additional coursework that develops research skills, knowledge of information systems, word processing skills, computer database skills, and knowledge of the internet will be helpful.

Wage estimates – Wage information specific to this occupation was not available. The 1997 Texas mean wage for a similar occupation, broadcast news analyst (OES 34014) was $20.86 per hour. (source: Texas Workforce Commission/ Labour Market Information Department)

Outlook – Outlook information specific to electronic research technicians was not available. As both personal and commercial usage of the internet increases, demand for this occupation will increase.

Associated titles – DOT: 131.262-014 newswriter, 131.262-018 reporter; O*NET: 34014 broadcast news analysts, 34011 reporter and correspondent; Other: electronic information specialist, data acquisition and verification technician

Source: www.soicc.state.tx/emerging/excel_html/e_research.htm

Chapter 5: Identifying the pathways—from the national innovation system to skill requirements

From research to skill needs: Overview

How does the research performed in the national innovation system influence the skills that employers require of their workers? Ideally, for those forecasting future skill needs, the path would be clear and direct. Research would lead to ideas for new or improved tools, systems, processes, products, or work practices. These ideas would be developed and the outputs commercialised (taken to market) in the case of a tool, product or system, or information about them disseminated, in the case of a new work practice. Depending on the nature of the particular output and how widely it was adopted, workers might then be required to upgrade their skills or acquire new skills to operate new equipment or implement new work practices, for example. This idealised path is shown in figure 5.1 below:

Figure 5.1: From research to skill needs—an idealised path

1 **Research** – ideas and knowledge for new or improved products, solutions, practices, etc.	2 **Development** of ideas into outputs e.g. product, tool, process, etc.	3 **Commercialisation** and/or dissemination of outputs and application/ adoption by industry	4 **New or upgraded skill** required in industry to operate/use/produce outputs
→	→	→	

If this model existed, those wanting to forecast skill needs could examine the research outputs under development in stage 2 (or even the utility of the ideas coming out of stage 1) and combine information about their characteristics with data on existing skills, to estimate whether new or upgraded skills would be required. The scale of the training required could be estimated on the number of industries or enterprises adopting or implementing the research output in stage 3.

In reality, of course, this clear path does not exist and the task faced by skills forecasters is much more difficult. To begin with, not all research leads to ideas for new products or solutions to problems. Much research provides underpinning knowledge for further research—or raises new questions for investigation while finding answers to others. Secondly, the linear process represented by this model (i.e. research to development to commercialisation and/or dissemination) misrepresents reality, which is much more messy and complicated. It implies clear boundaries and smooth transitions between the three stages when in practice some things occur at the same time; for instance a commercialisation strategy might begin to be framed even while the product for commercialisation is still being developed. The model also tends to place industry and enterprises outside the process as a recipient of a research output, where in fact both can be researchers, developers and commercialisers in their own right (e.g. pharmaceutical companies with large research laboratories), or partners in some or all of the process with a research organisation.

Many factors will affect whether a research output is adopted or implemented and whether a change in skills is required. Looking at each stage individually:

The research stage

Even the best ideas emerging from research will not necessarily enter, or later complete, the development phase. There can be many reasons for this:

- Insufficient financial support may be available for further work.
- The skills to develop the ideas may not be available.
- The costs of developing the ideas might be prohibitive.
- The end-product might be seen as having only a very small potential market and therefore returns might be judged too small to justify investment.
- Competition from other products etc. might be judged as too fierce.
- There may be doubts about the quality of the end-products.
- The potential of the ideas themselves may be overlooked.

An idea that is developed into an output such as a new tool, process, product or work practice faces another set of difficult tests in being successfully commercialised or taken up by industry or enterprises through dissemination:

- Development might have taken so long that potential users have adopted competing products that they are now committed to using. So there is no market.
- Consumers might be resistant to the idea of changing to something new and so industry may be unwilling to invest in it.
- Industry/enterprises might judge a new tool, system or process as too expensive to adopt, for instance, if adoption will require large-scale re-training of existing staff.
- An industry standard might have developed, officially, or informally, around an alternative, thus limiting the market.
- Industry/enterprises might not get sufficient information to judge whether the development is worth pursuing.
- There might be insufficient capital available to support implementation of a new tool or system or to set up the systems to manufacture and market a new product.
- There may be no appropriate existing industry or enterprises with the skills and facilities to manufacture and market a new product.
- A dissemination strategy may not reach those who could use the information.

An innovation that overcomes these obstacles and is adopted by industry/enterprises may still not lead to a requirement for workers to upgrade their existing skills or acquire new ones. A new product may simply add a line to an existing suite of products—and its manufacture draw on existing skills. A new tool, or other piece of equipment may require only existing skills in order to be used effectively. New or updated skills will be required only where there is a significant difference between the innovation and whatever it replaces or complements. As it was noted in chapter 3, some innovations are competency-destroying because they completely replace, rather than amend, whatever already exists. This is the case with some new technologies, and in these cases skill requirements may change substantially.

Sometimes a new tool or system will simplify a task that previously could be performed only by experts. This is happening with the implementation of new diagnostic tools in medicine and other fields. As they are adopted, these innovations free up experts for more creative work and enabling workers with lower-level skills to take on tasks that in the past required a degree of expertise. This technician will then require some training to perform the task effectively.

For all these reasons, in assessing whether new or upgraded skills will be needed as a result of the adoption or implementation of an innovation it is important to consider the particular characteristics of the innovation carefully and to compare it with what already exists. In some cases workers may only need to make minor adjustments. In others, more radical shifts will be required.

We now move on to consider the main issues discussed here in relation to the Co-operative Research Centre program. In this context, further attention is given to what happens to innovations that have no clear connection to an existing industry. We also note some specific types of innovation arising from the research of several different centres and their likely impact on skill requirements.

From research to skill needs: The Co-operative Research Centre program

Within the national innovation system, the Co-operative Research Centre program is primarily seeking research solutions to 'problems'. Broadly defined, these problems include quality issues, inefficiencies in systems and processes, and inabilities to perform particular functions, or meet required standards. The goals are to find ways to do things better or produce better things. Perhaps more than most other organisations in the national innovation system, the work of co-operative research centres is expected to result in tangible outputs that industry and other identified 'end-users' can benefit from.

The guidelines for the Co-operative Research Centre program for 2000 (DISR 2000) state their four main objectives as:

- to enhance the contribution of long-term scientific and technological research and innovation to Australia's sustainable economic and social development
- to enhance the transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia
- to enhance the value to Australia of graduate researchers
- to enhance collaboration among researchers, between researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources.

(CRC Guidelines 2000)

To achieve these objectives, all co-operative research centres are expected to involve industry or other potential end-users of the products of their research in key areas of their work. Their work is expected to have strategic relevance and their research outputs to produce outcomes of economic, environmental or social benefit to Australia.

Many different organisations participate in co-operative research centres. Core partners are signatories to the Commonwealth agreement and provide substantial support to the centre. Many core partners are universities—all such centres include at least one, but usually more. Government research organisations (e.g. the Commonwealth Scientific and Industry Research Organisation) government departments (e.g. primary industry) and semi-government organisations are also frequent partners. Others include publicly listed Australian enterprises (e.g. Pacific Dunlop, Telstra, ERG), overseas multinationals (e.g. Siemens; Hawker De Havilland, Ford and Nissan) other private enterprises and industry bodies.

In addition to core partners, co-operative research centres include participants or affiliates. These may also be signatories but make a lesser contribution than core partners and other contributors.

Except where a university is a dual-sector institution, (i.e. it has a TAFE division such as Northern Territory University, Royal Melbourne Institute of Technology, Swinburne, Victoria University) only one centre, the Australian Photonics Co-operative Research Centre, has a VET-sector organisation, NSW TAFE Commission, among its core partners. However, several other centres have other types of connections with VET, including a memorandum of understanding between the Co-operative Research Centre for Sustainable Tourism and the industry training advisory board Tourism Training

Australia. These VET links are discussed extensively in chapter 5. While largely informal, they provide a conduit for new knowledge created in the centre to flow into the VET system.

Co-operative Research Centres are substantial organisations, with an average budget of about $7 million per year, supporting about 30 full-time research staff. Thus, they are able to support a considerable number of activities and exploit the benefits of a critical mass of researchers and research resources. All participating organisations are expected to provide substantial financial (or in-kind) support to supplement Commonwealth Government funding.

Commonwealth funding for these centres extends for seven years, subject to periodic review. Most centres follow a program designed to be completed within this period within which there are usually three types of sub-programs:

- A *research* program comprising a number of different projects, often grouped around a small number of themes or issues.
- A program to *disseminate information* about the centre's work and/or commercialise its outputs.
- An *education and training* program, primarily for postgraduate education but sometimes also including the provision of short courses and workshops for industry and public education.

The last two programs sometimes overlap as the provision of public education and short courses for industry helps to disseminate knowledge of the centre's research and its outputs.

Co-operative research centre research programs and their outputs

Research activity within industry-focussed co-operative research centres is extremely varied and is hard to categorise. In a single research program there may be a variety of research projects with different objectives, rationales and expected outputs.

Most of the research is designed to lead to improvements in products, or better ways of doing things, in mature industries. For instance, the Australian Cattle and Beef Co-operative Research Centre is researching techniques to improve the quality of beef, several of the centres in the field of medicine are seeking to improve diagnostic methods and equipment, and in the mining field, centres are seeking better methods of identifying and mapping deposits of resources such as oil and ore.

Several of the centres are working to change the culture of mature industries. The centre for sustainable tourism, for instance, aims to advance the application of the principles of sustainability within the large and mature tourism industry. Its work is progressing new management systems, design principles and assessment methods. The Co-operative Research Centre for Cast (metals) also aims to shift a mature industry toward new methods and work practices.

A small group of the centres are working with new, rather than mature industries. Several are working to develop new and improved equipment, techniques and systems for application in the new and rapidly growing environmental industry, developing products to assist industries and communities to meet their responsibilities under local, national and global environmental acts, regulations and treaties, this includes, for instance the centres for water quality and waste management and pollution control (see case study reports online). This industry has been boosted by extensive Commonwealth Government support through an action agenda instituted by the Department of Industry, Science and Resources and is expected to grow substantially.

The Co-operative Research Centre for Landscape Evolution and Mineral Exploration is developing equipment that will have application in another new industry developing around Australia's need to counter dryland salinisation. This de-salinisation industry, which we have dubbed 'saltonics', is also benefitting from substantial levels of public funding support and is predicted to expand substantially.

The Co-operative Research Centre for Renewable Energy is another centre working in a new industry—although one that has been around for some time and is moving toward maturity. This centre is working to improve and extend the range of products available in the industry and techniques to increase efficiency, for instance in remote area power systems and wind generators. This industry is also developing rapidly with assistance from government support, including subsidies to consumers to purchase renewable energy products.

Only the Australian photonics centre is working with an industry that could be classified as emerging. Research and development in this field has been underway for several decades, but only in recent times has consumer demand for increased telecommunications bandwidth, for example, to support the internet, combined with a technological capability to result in a suite of new products, around which a new industry is emerging. The first industry association has only recently been set up and many of the products are still in the developmental phase. (As we noted in chapter 3, this industry is now beginning to recognise a need for technical skills in its workforce in the near future.) This centre is one of the very few to set up spin-off companies to house its intellectual property and develop and market its outputs. It is thus positioned at the nucleus of the emerging industry.

One other centre—satellite systems—is working where at present no industry exists. If the centre is successful, and this leads to the production of a suite of new products and services, then a new industry may develop at some time in the future. This co-operative research centre is still in the early stages of its seven year term, so potential for a new industry remains a considerable distance down the track. Developments in this centre should be monitored for an emerging need for technical skills.

Although most co-operative research centres are usually aligned with one particular industry, from time to time their research leads to innovations useful in another industry. For instance, landscape evolution and mineral exploration, and its development of equipment for use in the mining industry, has proved useful to the 'saltonics' industry. For this reason, it would be wrong to assume that the research performed in each centre has an impact solely on the industry with which it is most strongly affiliated. These impacts might include the development of skill requirements.

Figure 5.2 maps the research orientation of the centres along two axes. The first indicates the potential commercial outputs of the research and whether they are likely to be in new or existing industries and markets. The second indicates the type of research being conducted and whether it is based on improving something that already exists (incremental innovation) or if it represents a complete break from what exists and thus is really something new (rapid innovation).[6] Each number in the matrix refers to a specific centre as indicated in appendix 1. Some are represented in more than one cell of the matrix because some of their research projects have different orientations.

The diagram shows that by far the majority of research in the co-operative research centres is oriented to existing industries and markets (cells A and B) and much aims to build on or improve what exists (gradual innovation—cells A and C) rather than to come up with something completely new (rapid innovation—cells B and D). Only a small proportion of the research is indicated in cell D, the most radical orientation, and from which the production of new industries might be most expected. The diagram thus supports the view that on existing evidence there is limited potential for development of new industries from the centres' research. However, there is significant potential for the research to impact in existing industries, whether new or mature.

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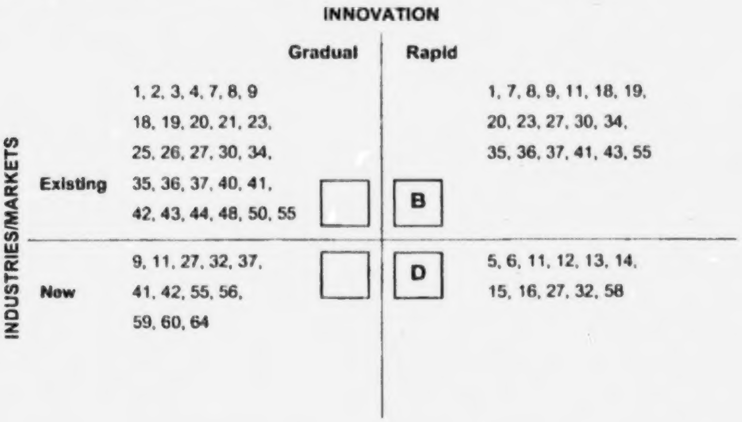
[6] This matrix was originally developed by Newton (1999) to identify investment opportunities in small cap companies.

Figure 5.2: The research orientation of the co-operative research centres



Looking more closely at the specific research projects being conducted in these centres provides a further indication of the potential of this work to influence skill requirements. In some cases, particularly in the medical field, the skills affected are likely to be at a high level, and therefore of more concern to higher education than to VET. Table 5.1 identifies those conducting research that may affect VET-relevant skills. About 40% of the 67 co-operative research centres examined for this project (including some expired centres) are indicated. Highlighted centres are the subject of the online case studies of this report, which provide considerably more information about the research programs, potential outputs and likely impact on skill requirements of their work.

For the developments in table 5.1 to affect skill needs depends largely on successful marketing of their outcomes, so that industries and enterprises adopt or implement the new equipment, tools, work practices etc. that result from the work of the centres. For this reason, the effectiveness of the centres' commercialisation and dissemination strategies is therefore crucial.

Commercialisation refers to a process in which the intellectual property of a new product or process is transferred to a business entity for use or further sale. It generally implies that a product has a commercial or business application in a particular industry or market, that is, someone will purchase it, or pay for the right to use it. The commercialisation activities of the co-operative research centres tend to fall into two categories: the formation of 'spin-off or start-up' companies, and the licensing of intellectual property.

In the first category, intellectual property developed by the centre is housed in a new company, which develops a business and marketing plan for the product. For instance, innovations emerging from the Australian photonics centre are marketed by the formation of several different 'spin-off' companies, each with different patents and intellectual property. These companies both manufacture and sell the product into a diverse communications market.

Table 5.1: Co-operative research centres and their possible effects on skills relevant to the VET sector

CRC	Research and VET-relevant skill impact
Australian maritime engineering	Developing new ship design and construction systems and processes that may impact on skill requirements.
Materials welding and joining	Developing new welding methods and procedures for quality welding.
Bioproducts	New products generated will eventually be applied in commercial food production.
Intelligent manufacturing systems and technologies	A change in basic skills may be required if the new processes etc. are taken up widely in industry.
*Cast metals	Technology development of the cast industry for greater efficiency.
*Australian photonics	Photonics is a new technology that is being embodied in new products. Technicians will be required for manufacturing, service and maintenance of these products.
Sensor signal processing	New services/products will allow tasks previously carried out by experts to be undertaken by technicians.
*Satellite systems	Satellite solutions will require technical skills for operation.
Australian mineral exploration technologies	New products and processes for mapping the regolith will be useful in the fight against salinity and will change the current practices of geologists, drillers and environmental managers.
*Landscape evolution and mineral exploration	Tools for mapping landscapes and assessing salinity will require new skills geophysics, data collection and analysis.
Black coal utilisation	Developing new equipment for underground vehicles that will require new skills to operate.
*Renewable energy	Increasing the efficiency of existing products and developing new products.
*Viticulture	Focus on product and process improvement that will require some skill upgrading.
The cattle and beef industry (meat quality)	Developing new practices and process to enhance quality and sustainability.
Aquaculture	New process, technologies, systems and stock lines are being adopted in this new industry.
Sustainable cotton	Developing new agricultural practices for sustainability and ecological safety that will impact on production and therefore skills.
*Sustainable rice	New methods and processes are being developed to minimise water use and increase efficiency and product quality. Changes to current practices will be required.
Sustainable sugar	Changes to work practices will be required for new processes being developed.
Quality wheat	Developing techniques and processes to enhance product quality.
Molecular plant breeding	Developing new methods of improving disease resistance, minimising climate stressors and increasing quality.
Ecologically sustainable development of the Great Barrier Reef	Developing new management tools to support the Barrier Reef ecosystem.
Tropical rainforest ecology and management	Environmental management, eco-tourism and heritage.
Conservation and management of marsupials	New approaches being developed that are of relevance for veterinary nursing.
*Water quality and treatment	Developing new processes and management systems.
Weed management systems	High-tech solutions are replacing low-tech solutions with consequences for operator skills.
*Sustainable tourism	The centre is working out ways in which the principles of sustainable development can be applied in the tourism industry. New skills will be required in all aspects of the industry's operations, including resort design and development, management and evaluation.
Tissue growth and repair	Research program in wound repair may impact on nursing skills.
Cochlear implant, speech and hearing research	Training for audiometrists required to deal with new products being developed.

In the second category, a commercial partner of the centre, (usually but not always a co-operative research centres signatory) purchases a licence to use the product or service, or for the rights to produce and on-sell it. The product or service is marketed through the existing sales and distribution channels of this commercial partner. For instance, the Sensor Signal and Information

Processing Co-operative Research Centre has developed a diagnostic kit for identifying cancerous cells. This will be taken to the market through a licensing agreement with a medical equipment company. This company will on-sell the unit to pathology laboratories.

Dissemination describes activities to promote and increase knowledge and awareness of the research of the centre and its outputs. Centres use a variety of processes to reach the most appropriate end-users. Dissemination usually includes the production of documents (many of the centres produce a newsletter) press releases, conference papers and presentations, visits and consultations.

When major end-users participate in the work of a centre, the research will have a more substantial impact. However, not all end-users are identified, nor is it possible for all to be participants in the centre. Sometimes the products of the centre's work become public goods (e.g. Co-operative Research Centre for the Antarctic and Southern Ocean). These centres serve a social purpose and their outputs are likely to be unsuitable or inappropriate for commercialisation. In other cases, such as sustainable tourism, the industry with which the centre is principally aligned consists mainly of small and medium-sized enterprises, thinly distributed throughout the nation, often without the capacity to take part in research. Disseminating information about the research to these enterprises is a major challenge, as is persuading them to adopt or implement the centre's research outputs. This is not a reflection of the quality and utility of the outputs, but of the difficulties of identifying effective channels of communication.

In a number of centres, dissemination strategies are referred to as ***technology transfer***. This process is seen as particularly appropriate where an innovation might not have a specific ***commercial value*** of its own but could have a strategic or ***commercial effect***, for example, where its implementation could bring about a productivity improvement or an increase in quality.

Co-operative Research Centres often see the production of graduates and postgraduates for employment in industry as an important part of their technology transfer process. These graduates take with them knowledge they have gained through their participation in the centre's research and can apply this directly in practice. In this way some of the new understandings, products and processes arising from the research may be adopted.

Outreach activities are also part of the dissemination process of some centres and are usually undertaken to promote contact with the wider community to encourage interest, participation, understanding and use of the centre's work. Some centres have an impressive suite of outreach activities (e.g. Co-operative Research Centre for Renewable Energy), which aim to create links with many different sections of the community, including schools and interest groups. Others maintain a narrower focus on a small range of potential end-users of their research and perform few activities that could be described as ***outreach***.

The generally poor formal links that exist between the centres and the VET sector (which are discussed extensively in chapter 6) reflect a failure in most centres to identify VET planners, providers, teachers and students as having an interest in their work. Dissemination of research findings and outputs to VET is rarely considered in their work and there are few centres that support activities for this purpose. The centres for renewable energy and viticulture are exceptions that provide an example of best practice in this regard. Our case studies of these two centres, and also of the centre for sustainable tourism, show that the development of relationships with elements of the VET sector provide benefits to the centres in the form of access to other parts of the industry, to expertise in working with industry and in developing training. They also demonstrate benefits to the VET sector in the form of opportunities for VET staff to participate in cutting edge research and to upgrade and extend their knowledge, as well as speedy access to new knowledge so that it can be rapidly incorporated into appropriate forms of training.

As noted earlier, all co-operative research centres operate education and training programs and in many cases these also serve a dissemination purpose. Primarily the programs are designed for graduate and postgraduate training. However, in practice many centres take a broader view and so engage in a more diverse range of activities. We classified the centres' education programs into three categories:

Inward focus

Inwardly focussed education and training programs are concerned principally with sustaining research in the field through the training of new researchers, that is, with reproduction. These centres focus strongly on formal postgraduate education, with occasional professional development activities for staff members.

Semi-open

Semi-open education and training programs also focus strongly on postgraduate training, coupled with staff development, but include additional activities to disseminate research outcomes and outputs to professionals in industry, such as seminars, workshops and short courses.

Dynamic outward

Dynamic outward education programs include all of the activities of the previous two categories but in addition include initiatives to extend information and understanding of their work to a much wider audience, including schools, local councils, some community organisations and government departments.

Table 5.2 shows the number of co-operative research centres in each category according to their industry group. It indicates that most centres are in the inward-focus category, with the remainder split equally between the two other categories.

Table 5.2: Co-operative research centre education and training programs by industry groupings

Industry sector	Inward	Semi open	Dynamic
Manufacturing	3	4	2
Information and communication technologies	4	1	1
Mining and equipment	6	2	2
Agriculture and rural-based manufacturing	9	4	2
Environmental	4	2	7
Medical science and technology	5	4	1
Total	**31**	**17**	**15**

These results suggest room for improvement in many of the centres' dissemination strategies. However, dynamic education and training programs are not a requirement for funding and many centres may not have the resources to support them. In addition, where a research output is under commercialisation or has been licensed, commercial-in-confidence provisions may apply that preclude some dissemination activities.

Nevertheless, as we discuss in the next two chapters, access to information on the outcomes and outputs of the centres' work is a problem for the VET sector. This counters the timely provision of appropriate training. If, for instance, VET providers only find out about a new piece of equipment when it is released onto the market, and operators of this equipment will require re-training, there will be a gap (perhaps substantial) between when the skill is required and when appropriate training becomes available.

Discussion: Responding to changed skill requirements

We have noted that research is most likely to result in a new or changed skill requirement when it leads to the development of a product or other output which is different from what already exists and which is successfully commercialised or disseminated and taken up by industry and enterprises. We have noted also that whether a research output is successful—or is left on the shelf—depends on many factors not necessarily connected with the quality of the innovation. Success in the market, for instance, may depend on other products available, consumer views and preferences, and the speed with which the product reaches the market.

In considering how skill requirements arising from the centres' research should be addressed, there are some important issues to take into account. Firstly, a skill requirement will not always translate into a formal training need. It may be possible for employers to acquire the new skills they need through recruitment, for instance, or through arrangements such as coaching or mentoring. This might be the case where the new skill builds on the existing skill base, or where few workers are involved.

Secondly, meeting a training need may not necessarily be the responsibility of the public VET system. It would be difficult to justify public expenditure, for instance, on providing a training program around an innovation that is adopted by only one or two enterprises or will only ever be used by a handful of firms and workers—unless there is some other reason for doing so, such as an external (e.g. national) significance. An innovation that is adopted or implemented to a very limited extent might best be addressed through some in-house initiatives or limited customised training on a fee-for-service basis.

Thirdly, how soon training will be required to meet a new or changed skill requirement will be affected by the speed with which innovations are adopted on a wide scale. Where existing industries comprise highly dispersed small businesses, this it may take much longer for an innovation to become commonly used—and therefore for a significant skill requirement to emerge—than it might take in an industry dominated by a small number of very large players.

Fourthly, an issue that emerges frequently from our case studies is 'contextualisation', that is, the re-framing of existing knowledge and skills within the particular understandings of the industry. In some cases, the adoption of an innovation may require traditional, rather than new skills, but understood and practised in a way specific to the particular industry. For example, the photonics industry will require technicians with traditional training in electronic engineering, but also with an understanding of the ways in which photonics technologies work and can be used—and the structure and culture of the industry itself.

Finally, and perhaps most importantly, responding to new skill needs only once they occur, may be too late. Given the time necessary to prepare appropriate training, and for workers to complete it, there may be a considerable period in which the adopted innovation may be used ineffectively, or uneconomically. A more pro-active approach is called for that anticipates skill needs before they arise. For this, stronger connections between the VET sector and the co-operative research centres are vital to expedite the flow of knowledge in both directions.

Chapter 6: Connections and disconnections—VET and the co-operative research centres

Introduction

As we have already indicated, one of the defining characteristics of the Co-operative Research Centres program is the strong focus on commercialising research outcomes. This focus aligns with the program objective to 'enhance the transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia' (DISR 2000). The program calls for the engagement of industry and other end-users in a centre's operation, integrating the work of researchers, industry and users into a collaborative approach that supports the creation and development of ideas and their transition into economic, environmental or social benefits and commercial success.

It is accepted and commonplace that in our market-driven economy success depends on innovation—that is, to generate ideas and commercialise them into market commodities (Dogson & Bessant 1996). This concept gives strong support for transferring research outcomes into products and commercial benefits.

Marceau, Manley and Sicklen (1997) note the Organisation for Economic Co-operation and Development's interest in 'knowledge distribution power' as a measure of economic performance suggesting that this focus on measuring knowledge ***distribution*** indicates that:

> … useful knowledge cannot be really said to be created unless it is part of a broader process of knowledge diffusion/distribution. Knowledge creation and diffusion should thus be understood as part of the same process. (p.4.11)

This diffusion of technological knowledge is commonly referred to as ***technology transfer***—the process of conveying the 'knowledge about technology and its use, from one party to another' (Dogson & Bessant 1996, p.12) and is critical to the success of the innovation to commercialisation cycle.

In the technology transfer process, vocational education and training, as a key player in industry workforce training, is arguably in a unique and important position to enable the timely introduction of new skills and knowledge. Developing and maintaining an innovation value chain that includes knowledge creation and knowledge deployment, results in a skilled labour resource and productive industry capacity. Thurow (1992) notes this connection, arguing that 'skilled labour will be the arms and legs that allow one to employ the new product and process technologies that are being generated' (p.51).

While the current national innovation funding tends to focus on knowledge creation efforts, primarily through university-led research and development, there is also pressure, especially in the Co-operative Research Centre program, to commercialise the research and development outputs, transferring and exploiting the new knowledge for economic benefit.

This commercialisation imperative and the transfer and transformation of existing new knowledge has implications for institutions involved in industry training. As Teubal, Foray, Justman, and Zuscovitch (1996) argue 'the transfer and transformation of existing and new knowledge, mak[es] the stock of knowledge more socially useful … exploit[ing] existing knowledge and facilitat[ing] the accessibility of the stock of knowledge' (cited in Marceau et al. 1997, p.4.15). Implicit here, but little recognised, is the need for the VET sector, as the primary industry trainer and one of the main conduits for much of the 'socially useful' knowledge, to connect with the research and development sector to ensure the timely development of a skilled productive society.

It is within this context that the connections and disconnections between co-operative research centres and the vocational education and training sector are explored in this chapter. Together with the detailed online case studies the chapter documents the nature of these relationships and their intended or unintended consequences. It highlights current relationships between VET and the co-operative research centres and the possibilities offered by the connections for the timely introduction of new knowledge and practice into VET. It also identifies some barriers to the flow of knowledge.

This is a story of connections and disconnections spread along a continuum, ranging from no connections through weak and tenuous informal connections to strong formalised relationships.

The chapter concludes by arguing that the VET sector should, in many cases, since it is not currently, be an integral player, in the centres' commercialisation, dissemination and education and training programs. Currently, VET is the missing link in the national innovation system. This is a tragedy because it could provide a sophisticated and nationally structured mechanism for the rapid introduction of new products, new knowledge and innovative practices into Australian industry.

Uncovering and identifying the connections

Initially, connections between VET and the centres were investigated in the annual reports of co-operative research centres. As very little evidence of connections was uncovered, it was decided to delve further, beginning with phone interviews with the chief executive officers and education and training managers of the centres. Through many subsequent discussions our understandings of the centres, their research programs and their relationships with industry and VET were strengthened. Some discussions led us on detective-like pursuit of individuals who could shed further light on the connections and disconnections. This included not only people from within the centres, but also people from industry and VET institutions. The issues continued to be explored in case study interviews.

As we indicated earlier, universities are at the heart of the majority of co-operative research centres. Discussions with centre personnel uncovered a general lack of awareness of VET among people from a higher education background. While some respondents indicated that a level of cultural and academic elitism was the cause of the lack of connections between VET and the centres (and indeed elitism was evident in a small number of cases) it soon became clear that in most cases, lack of awareness of, and familiarity with, VET is the main reason for their poor interconnections. Many respondents asked 'How is VET relevant to our work?' and after discussion followed up with 'Who would be the appropriate contact?'. It became clear that VET practitioners were also unaware of the centres, and lacked an understanding of how they could interact with them. Consequently, they missed opportunities to be involved with the cutting edge of industry development. The complex nature of VET systems and processes was also seen as a significant barrier to the formal, structural involvement of VET organisations in the centres.

Our investigations uncovered considerable diversity in the connections between VET and co-operative research centres. Some of this can be attributed to the flexibility of the program, which allows each centre to direct its own performance in education and training, and to the extensive range of research performed in the centres. A topology of the connections was developed of five categories: none, nascent, incidental, informal and strong. A sixth category, 'should be', was added later to identify centres which had no connection with VET but which had research programs in areas where there are currently specified VET courses or a recognised training capability.

Table 6.1 outlines the descriptions and conceptual differences between the six categories.

Table 6.1: VET–co-operative research centre connections

Connection type	Description
Strong	committed relationship generally formalised in an agreement or strong personal long-term commitments
Informal	links that support intermittent information transfer or efforts to form links
Incidental	one-off contacts to address a specific need, often relying on informal individual contact from either the CRC or VET
Nascent	the CRC perceives value in a connection with VET and is looking to connect but has had no previous connection
None	no connection evident
Should be	research programs align with VET areas

It was not always easy to assign a centre clearly to a particular category. The relationships documented tended to change over time, even during the period in which the research was conducted. This may have in part reflected our intervention, which tended to produce a growing awareness and recognition of the VET sector as a user, or potential user, of centre research and knowledge.

Sometimes also, the boundaries between categories became unclear, thus reinforcing the notion of a continuum of relationships rather than clear groupings.

Overview of connections

The distribution of connection types across the centres' industry sectors, shown in table 5.2, provides an interesting perspective on the VET sector–centre connections. There are many more strong links in the fields agricultural and rural-based manufacturing, environment and manufacturing technology than in information and communication technology, mining and energy and medical science and technology. This is not surprising, given that VET has a strong training base in the 'strong' areas. However, it is interesting that there are also high numbers of 'informal' and 'incidental' links in the strong areas. This indicates that there may be significant room to develop and strengthen these weaker connections with VET.

The largest group comprises centres with no connections to the VET sector. Over one-third of the centres are in this category and many have a narrow industry focus with much of their research being directed toward commercial outcomes that will give core partners a competitive advantage. Consequently, their research findings may be considered commercially sensitive or in-confidence and therefore not open to public access. Nevertheless, many of these centres have research programs that are aligned to VET training, thus placing them in the 'should-be' category.

The 'should-be' category accounts for 15 of the 24 centres without VET connections. The centres in this group are spread across all industry sectors except manufacturing technology. The lack of connections in all but manufacturing is perhaps indicative of a continuing perception of the VET sector as 'the tech', with a historical focus on 'blue-collar' occupations.

Few (four) centres are identified in the 'nascent' category, that is looking to become involved with VET, but without any previous connection. Two of these are in the environmental industry—still a relatively new area for VET training.

Centres in the 'not relevant' category are indicative of the kind of research that is well removed from VET practice. The areas of mining and energy, and particularly medical science and technology, are strongly represented in this category. The co-operative research centres in these fields tend to perform research to produce outputs that is likely to have a greater impact on professional than para-professional occupations.

Table 6.2: Co-operative research centres and their connections with VET by industry sectors

Industry sector	strong	informal	incidental	nascent	should be	not relevant	expired
Agriculture and rural-based manufacturing	3	2	2		4		5
Environment	2	4	1	2	2	1	2
Information and communications technology	1			1	3		3
Mining and energy	1	1			4	3	1
Manufacturing technology	2	4	2	1			
Medical science and technology	1		1		3	4	1
Total	**10**	**11**	**6**	**4**	**16**	**8**	**12**

Connections

In the following sections, each of these six categories of connections is explored in more depth, using examples drawn from our investigations. The examples highlight the relationships between co-operative research centres and the VET sector, their nature and their consequences. The lack of relationships is also explored, bringing to the fore a rationale for VET involvement in the national innovation system.

Strong connections

We have defined strong connections as 'a committed relationship generally formalised in an agreement or strong personal long-term commitments'. This definition varies considerably, from formal legal agreements to strong informal arrangements that have developed, initially between individuals, but which have progressed to stronger institutional recognition and acceptance of a connection that may eventually formalise into more structured arrangements.

The co-operative research centres with the strongest connections to VET represent all six industry sectors (see table 6.3). In coming to understand this spread of strong connections across industry sectors it became clear that often personal networks are behind the connections. How these informal connections came to develop into strong formal and structural relationships varied with each centre. However, in general there is a net positive gain from these relationships that is recognised at management levels in both the centres and VET organisations.

Table 6.3: Co-operative research centres with strong connections to the VET sector

Industry sector	Co-operative research centres
Agriculture and rural-based manufacturing	Viticulture
	Cattle and beef quality
	Sustainable rice production
Environment	Tropical savannas
	Sustainable tourism
Information and communication technology	Australian photonics
Mining and energy	Australian CRC for renewable energy
Manufacturing technology	Intelligent manufacturing systems and technologies
	Molecular engineering and technology
Medical science and technology	Aboriginal and tropical health

The following descriptions of these strong connections indicate the diversity even within a single category. The strongest structured relationships are presented first, before the less formalised and structurally weaker, but still strong, relationships.

Australian photonics

NSW TAFE is a signatory in the Commonwealth agreement for the Australian Photonics Co-operative Research Centre. As such, NSW TAFE is a core partner, working with the centre to provide vocational education and training and advice on issues including the development and accreditation of courses specific to the needs of the emerging photonics industry. In short, TAFE NSW is fundamentally responsible for the centre's performance in vocational education and training.

The development of the photonics–NSW TAFE relationship is documented in chapter 2 and comprises one of the online case studies. Briefly, it arose out of the work of the NSW TAFE Industry Partnership Centre in the *Photonics in Australia* project funded by the Commonwealth Department of Industry, Sciences and Tourism and undertaken by the Warren Centre for Advanced Engineering. As a result of this involvement and the move of the photonics centre to the Australian Technology Park, the same location as the Industry Partnership Centre, a dialogue began between the two centres. The outcome was a strong working relationship cemented in 1998 through a memorandum of co-operation to assist in the transfer of knowledge into the VET system.

This connection has enabled the development of a framework for the timely development of vocational education and training in photonics and assists the centre to train skilled workers for its spin-off companies. For an analysis of the types of links possible between VET and the co-operative research centres 'spin-off companies' we refer the reader to *Going boldly into the future: Skills and Australian high technology start-up firms.*

Viticulture

This connection is reported in one of the online case studies. Briefly, the Co-operative Research Centre for Viticulture has a strong structural connection with the Wine Industry National Education and Training Advisory Council. The council is a core partner and signatory to the centre's Commonwealth funding agreement and, as a core partner, manages their viticulture education program. This is a significant task with responsibility for providing a whole-of-industry approach to education and training, ranging from entry-level operational training at the vineyard or winery, through para-professional levels for industry management to the graduate and postgraduate levels of industry research. The inclusion of the council into the centre initially met some resistance from some academic members of the centre. However strong industry lobbying persuaded other centre members that the advisory council would provide the research outcomes and outputs to flow rapidly into work practices. This decision has been vindicated with a rapid uptake of new practices based on the viticulture centre's research. It has resulted in Australian wines being highly placed in the world market.

The council also represents the wine industry in the National Food Industry Training Council where industry training standards for the VET sector are determined. In this role the council revises, identifies and adds units of competency to the national industry training package.

Australian Co-operative Research Centre for Renewable Energy

The connection between the Australian Co-operative Research Centre for Renewable Energy and VET arose from common interests between people working in the same field—in this case renewable energy—and meeting through professional networks. This is a common story in developing links between the co-operative research centres and the VET sector and serves to highlight the importance of VET practitioner involvement in professional networks.

The connection is described extensively in one of the online case studies. The centre provided funding for the Renewable Energy Centre at Brisbane Institute of TAFE to redevelop an existing Certificate IV course for flexible delivery. Through the relationship, the institute gained access to new knowledge that it can rapidly include in its programs and course materials. Flexible delivery of the course has opened up access to training in renewable energy across the country. For an industry with a technical skills gap, this is an important development that will have longer-term benefits.

Initial funding of the course development was on a return-on-investment basis, with TAFE paying royalties to the centre for sales of training materials. This arrangement now provides both parties with an income stream that has enabled the TAFE personnel in particular to take up some new professional opportunities.

An interesting recent development is that the centre has applied for registrations as a training organisation so that it can expand into providing accredited training.

Sustainable tourism

This connection is also described extensively in the online case studies. The centre has a link to VET through a memorandum of understanding with the national tourism industry training advisory board, Tourism Training Australia. This connection, like many others, developed through a personal and longstanding connection between the centre's industry extension manager and the chief executive officer of Tourism Training Australia and the centre's need to disseminate its research outcomes to the many small and dispersed businesses that dominate the Australian tourism industry.

In developing the relationship with Tourism Training Australia, the centre's chief executive officer, Professor Terry De Lacey, sees the industry training advisory board primarily as providing avenues through their 'sophisticated network of contacts' for reaching parts of the tourism industry that are otherwise disconnected from the centre. He favours the development of the relationship on a commercial basis, for the delivery of centre products and related training and support.

Tourism Training Australia also sees substantial benefits in the relationship with the co-operative research centre—and a potential for more as the connection develops further. It notes the need for a stronger research base in tourism to sustain the industry and is keen to be involved in, and to influence, research. The relationship works, the advisory board believes, because the centre has strong links with the universities, but weaker links with industry, and Tourism Training Australia is able to fill these gaps through its extensive network of contacts.

Intelligent manufacturing systems and technologies

In 1997 the Co-operative Research Centre for Intelligent Manufacturing Systems and Technologies discussed with the directors of TAFE divisions within two dual sector institutions that are core partners the possibility of developing a training program for TAFE teachers that would introduce them to cutting-edge manufacturing technologies. An agreement led to a collaboration in 1998 with the Royal Melbourne Institute of Technology, the Department of Industry, Science and Resources, and the Advanced Engineering Centre for Manufacturing to develop a training module under the centre's education sub-program entitled 'Training for TAFE sector personnel'.

The module was the outcome of the centre's vision that for industry to embrace new technology, those providing education and training for the industry needed to be familiar with the technology. The VET sector was targetted because the centre recognised the role VET organisations play in industry training and that VET training can be an effective mechanism to diffuse new knowledge.

The centre recognised its own poor understanding of the VET sector and used the structural links that already existed between the centre and the dual sector institutions which are its core partners.

Aboriginal and tropical health

Much of this centre's work is aimed at producing policy to guide service delivery to indigenous communities, but the centre also has a strong VET connection through its indigenous education and training program. This program aims to increase the health management and self-education capacity of indigenous communities by providing education and work opportunities to Indigenous youth. The centre and its core partners have a strong mentoring role in encouraging further study from VET certificate level through to postgraduate levels. This is unique among the co-operative research centres.

The centre actively brokers training for indigenous people beginning at the Certificate 3 level. Group training companies, core partners and VET providers are co-ordinated by a co-operative research centre VET co-ordinator to select, place and train indigenous students. The Certificate 3 training is intended to begin students on an educational pathway that will have a positive influence in their communities.

The integration of VET training for indigenous people has been innovative and developed strong connections with the centre. The success of the program will ensure continued work with the VET sector to support the centre's work.

Sustainable tropical savannas

In supporting sustainable land use practices in the northern regions of Australia the centre for sustainable development of tropical savannas has developed a formal involvement with the Northern Territory University to develop VET-level courses for land-holders in Australia's tropical regions.

The Northern Territory University is a dual sector institution and as a core partner in the centre the links between the centre and VET are formalised. The centre has developed a greater understanding of VET systems and processes through its part in developing a Northern Savannas training package, but finds that in course development VET lacks the responsiveness required to support the rapid introduction of new knowledge into a training area. It considers the processes cumbersome with 'too many boxes to tick'. This experience indicates a barrier to VET connections with the co-operative research centre. However, the close relationship with VET personnel at the university will further support the collaborative work and ensure that the centre's research findings are applied in the field.

Cattle and beef quality

Links to the VET sector are a feature of this centre's education and technology diffusion program. The centre's awareness of the capacity in the VET sector to disseminate knowledge to the industry through training led to a decision to fund NSW TAFE to develop training units that incorporated the centre's research outcomes. The centre has also worked with the national Meat Industry Training Advisory Council in developing the meat industry training package.

The centre's director (Bernie Bindon) is supportive of the interactions with the VET sector. While the centre is not continually pro-active in approaching VET in a formal way he recognises that further collaboration will be needed to meet the growing need to disseminate the centre's knowledge at the operational level—particularly to smaller producers.

TAFE students are regular visitors to the centre's beef cattle feedlots. Strong relationships have developed between Western Institute of TAFE teachers and centre staff with the TAFE teachers deliberately pursuing connections with the staff. The centre also actively supports engagement with the Western Institute of TAFE. Peter Dundon of the centre has played a pivotal role and, according to the national Meat Industry Training Advisory Council, has been the key VET contact within the centre. Through Peter strong relationships and networks between teachers and the centre have been achieved and are now considered to have reached a stage where they will be able to continue without his direct intervention.

Sustainable rice production

This centre is the subject of one of the online case studies. Like many other agricultural and rural co-operative research centres, which have strong connections through their respective departments of agriculture and the associated agricultural colleges, the centre for sustainable rice production provides new knowledge and information on rice production to farmers through its core partner, NSW Agriculture. NSW Agriculture acts as a conduit for the diffusion of new knowledge and practice to the farm, through an extension program of field days and short courses. NSW Agriculture also produces state-accredited courses based on the national training packages for delivery at their agricultural colleges. The centre's engagement with other VET providers in the rice production area, such as TAFE NSW, is fragmented and negotiated informally at a local level. This engagement includes teacher and student visits, field days and guest lectures.

A further link exists through a core partner in the centre, the Ricegrowers' Co-operative Limited, which has recently developed an enterprise training package in conjunction with the national and NSW Food Industry Training Council. Courses are being delivered at the Griffith campus of TAFE NSW.

While the centre management acknowledges that it has little understanding of the VET sector and is concerned about the complexity of the VET sector and its ability to respond to niche training needs, the established links to VET through the centre's core partners support the transfer of research outcomes.

Molecular engineering and technology

The Co-operative Research Centre for Molecular Engineering and Technology has expired, but its work has resulted in the formation of a spin-off company AMBRI Pty Ltd, currently owned by Pacific Dunlop Ltd, which is a registered training organisation. This status allows it to determine, organise and deliver its own training. AMBRI is a developing company that has some specific training requirements. Using Pacific Dunlop Ltd's registered training organisation status it has been able to target specific areas of need on site and at present is delivering frontline management training

AMBRI is also seeking to develop relationships with an appropriate TAFE partner for training in other areas such as clean room operations, safe laboratory practices and occupational health, safety and welfare. This would enable it to make use of economies of scale in providing the broad range of skills needed in a developing company and industry.

In this case the VET connection developed very late in the life of the centre, but at a critical time for the commercialisation of its research outputs. At this stage the main role of VET is to provide the day-to-day business and production skills to support the enterprise's development.

These short descriptions show that strong connections develop between co-operative research centres and the VET sector when a centre encounters a need to reach the end-users of its research and recognises that VET can assist it in this task. The links often begin with personal connections but develop into more formal arrangements which included memoranda of understanding, VET teacher and centre collaboration in course development, collaboration with industry training advisory boards to support training package development and financial agreements. Strong personal networks at several levels in both the centres and VET organisations are also important in initiating and supporting connections.

Informal connections

Informal connections support intermittent information transfer or efforts to form links. They can be robust relationships but they are not supported by the commitment of ongoing funds or in-kind support. Rather, they are characterised by an intermittent or low level of knowledge exchange.

Table 6.4 indicates that 'informal' connections occur in three main industry sectors. In the case of agriculture and rural-based manufacturing and manufacturing technology they are consistent with the areas of traditional VET involvement. The large number of environment centres with informal connections is also consistent with this industry sector, which is still a developing area for VET training.

Table 6.4: Informal VET connections by industry sector

Industry sector	Informal connections
Agriculture and rural-based manufacturing	Premium quality wool
	Sustainable sugar production
Environment	Water quality
	Ecologically sustainable development of the Great Barrier Reef
	Conservation and management of marsupials
	Weed management systems
Information and communication technology	
Mining and energy	Landscape evolution and mineral exploration
Manufacturing technology	Materials welding and joining
	Cast metals manufacturing
	Advanced composite structures
	Polymers
Medical science and technology	

The informal connections include cross-institutional lecturing, informal personal interactions, industry links, champions and the use of equipment. Stronger connections have not yet developed from these links for a variety of reasons including:

- lack of understanding in the centres of VET systems and how to connect
- centre views that VET course accreditation processes are too complex
- the centres note that establishing connections with VET are not among their current performance indicators
- lack of interest by VET practitioners in engaging with the centres
- loss of key individuals who initiated contacts
- centres have higher priorities and interests elsewhere.

Cross-institutional lecturing, usually on a casual or part-time basis, involves individuals from co-operative research centres teaching in VET institutions. This occurs primarily in the manufacturing technology centres of materials welding and joining, Cast metals manufacturing and polymers. Staff from the Sustainable Sugar Co-operative Research Centre also teach in the regional agricultural colleges. These connections allow knowledge from the centre to be covered in classes and used in course materials. However, the connections are reliant on individual commitment by centre staff to teaching in VET and on continued VET demand for their services. Lack of demand for training for skilled workers, despite skill shortages in industry, is apparent in many manufacturing areas and has led to difficulties in maintaining the links.

Informal personal interactions occur where individuals from a centre and VET have common social or industry connections. This occurs in the centre for the conservation and management of marsupials, the centre for premium quality wool, and the centre for land evolution and mineral exploration. These interactions have a number of different outcomes, including cross-institutional lecturing.

The centre for the conservation and management of marsupials has an indirect but long-standing informal relationship with Sydney Institute of Technology. A centre researcher, also a member of staff at Macquarie University, collaborates with an institute teacher to provide a one-day workshop on the care of marsupials, which has been a requirement for completion of the animal care certificate at the institute. The informal and unstructured nature of the connection means that with changes to the new veterinary nursing certificate, which have resulted in the subject becoming optional rather than compulsory, it is possible that the centre's connection may cease if there is a decline in the number of students.

In the Co-operative Research Centre for Premium Quality Wool the technology adoption manager trained as a wool classer in a VET institution and has maintained an active but informal engagement with the VET sector through membership of the woolclassers' association. Continued informal interactions with VET personnel allowed some of the centre's research outcomes to flow into VET. Through this experience, an understanding developed in the centre of the VET sector as an end-user of its work and an investigation began into the possibility of developing the centre's 'Woolwise' training resources into a VET-based wool course. However, the investigation concluded that this would be a 'difficult' and 'tedious' project and that 'the hurdles (are) too difficult for gaining accreditation'.

The unfortunate experience of this centre highlights a consistent barrier to the inclusion of new knowledge arising from their work in courses in VET. The complex processes of development and accreditation in VET have caused many centres to stay at less formal level of involvement.

The centre for land evolution and mineral exploration provides another perspective on informal relationships that connects VET and co-operative research centres. Canberra University and the Australian National University have a long-term connection with Canberra Institute of Technology's science and technology faculty. Beginning during the mineral exploration boom in the 1970s, graduates from the Geoscience Diploma at the institute have regularly transferred and gained credit for the first year of university geology courses. This has developed a strong relationship between the centre's education and training manager and the institute and an understanding in the centre of VET's capabilities. This connection may soon cease as the Canberra Institute of Technology is finding it difficult to maintain the geoscience course due to low student numbers. However, the centre's awareness of VET capability and its involvement in the potential development of a 'saltonics' industry (as discussed in the land evolution and mineral exploration case study online) will lead to a stronger involvement with the VET sector in the future.

Another informal type of connection often occurs through the centre's industry partners. For example, the environmental centre for water quality has strong connections to the water industry through its industry partners and is also a member of the South Australian Electrical, Electrotechnology, Energy and Water Training Board. The centre is also involved with various industry committees such as the Water Industry Council of South Australia and the Water Industry Education and Training Association. At present the centre is not actively working to influence VET training in the industry. However, it has developed connections that will provide channels for future involvement.

Also of interest in relation to the water quality co-operative research centre is the approach taken by the water industry trainers and lecturers who work at the VET organisation, the Queensland Open Learning Institute. These university graduates are aware of the centre's work (e.g. through professional conferences), and include material gleaned from centre communications (e.g. newsletters etc.) into their courses. This happens also at the Water Training Centre based at Deakin University's Waurn Ponds campus. In other VET water training centres however, training is delivered by trades-trained teachers who are unfamiliar with the concepts and other material developed by the centre. This story highlights both the usefulness of the centre's research to VET training and the cultural and contextual barriers to the flow of that knowledge into VET.

The story of the development of the heritage interpretive tourism course by the Co-operative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef in conjunction with Cairns TAFE and the tourism industry provides an example of the role 'champions' can play in establishing connections, but also of the often tenuous nature of these connections. The development of the course arose from a desire to develop a greater understanding of the region's heritage in visitors to the Great Barrier Reef. Tour guides were to be trained to deliver related information. The project was 'championed' by a centre staff member who recognised the role VET plays in training for the tourism industry.

The course was intended to be continually reviewed and updated by the collaborators as new information and understanding about the Great Barrier Reef and surrounds came to light. However, with the departure of their VET 'champion', the centre's involvement has become negligible. There is still recognition in the centre that some involvement is warranted. However, VET personnel perceive that the centre's 'academic agenda', funding and 'research agenda' are working against collaboration. Thus the hard work of the champion in developing collaboration has been lost because broader structural links have not been achieved.

A similar situation has occurred at the Co-operative Research Centre for Weed Management Systems. This centre has used agricultural colleges to accredit courses in weed management but has had difficulty in maintaining connections with the VET sector due to staff changes there. These have made it difficult to maintain interest in developing weed management courses. The centre has now taken a more linear approach to knowledge dissemination and moved away from interactive course development to the provision of training materials to supplement existing courses. The failure of VET to capitalise on the opportunity to develop a strong interactive partnership with the centre has reduced the capacity of VET to play a leading role in training for weed management.

Sharing equipment has also provided an opportunity for collaboration between VET organisations and co-operative research centres. For instance, in the case of the centre for polymers, core partner, the Royal Melbourne Institute of Technology, a VET provider, enabled Chisholm TAFE College to gain access to polymer die-casting equipment. While there is no formal arrangement between the centre and Chisholm TAFE this link has led to the involvement of VET lecturers in delivering part of the graduate polymer courses at the institute and has thus led to the informal introduction of new knowledge into VET. Unfortunately however, there is little demand for entry-level training for the polymer industry and little VET provision, thus the centre is under little pressure to support VET-level training.

In several cases, the absence of performance criteria specifying co-operation or interaction with VET is used by the centres to justify the maintenance of only informal or tenuous connections. The centre for advanced composites, for instance, makes it clear that low student numbers in VET in this field and the closure of training facilities limits their involvement in VET. This is despite efforts to assess and support the development of VET-level skills in this industry. As there is identified industry demand for undergraduate and postgraduate training, however, and the centre education program guidelines focus on university-level education, the centre has been able to excuse itself from a structured approach to VET training.

An important theme that emerges from these stories of informal connection is that if barriers can be identified and addressed stronger connections will develop. Clearly there is a significant need for the VET sector to be pro-active in seeking out connections to support the maintenance of course content and to introduce new knowledge. VET also needs to understand the misunderstandings and misconception of VET that are held outside the sector—and perhaps particularly in the national innovation system. VET also needs to consider the implications of downgrading facilities when research shows that there is considerable potential for development in the industry.

Incidental relationships

Incidental connections are similar to 'informal' connections but are one step further removed. Moreover, they are transient. The connections do not necessarily have an education focus and are generally the result of a specific need identified by either a co-operative research centre or an organisation or individual in the VET sector. Commonly, there are no personal connections supporting these engagements nor are there usually attempts to maintain a connection. These links exist at a particular place and time with no commitment from either party to placing them on a more secure or continuing basis.

Table 6.5 shows that the 'incidental' connections are thin and spread across four of the six industry sectors. Each case is unique.

Table 6.5: Incidental connections by industry sector

Industry sector	Incidental connections
Agriculture and rural-based manufacturing	Quality wheat Molecular plant breeding
Environment	Freshwater ecology
Information and communication technology	
Mining and energy	
Manufacturing technology	Bioproducts Australian maritime engineering
Medical science and technology	Eye research and technology

Quality wheat products and processes

It could be argued that this centre does not belong in this incidental connections category given that the co-operative research centre recognises the value of its research to VET, and the impact training has on the industry. Furthermore, it also recognises that the transient nature of a co-operative research centre calls for it to determine mechanisms and avenues to 'ensure valuable research outcomes go into practice independent of the lifespan of the centre'.

However it has been placed here because of the nature of its approach. That is, the centre provides information to the VET sector at times it considers appropriate rather than maintaining an ongoing involvement with VET. To achieve this a contact person in the VET sector who can assist in the dissemination process is identified and contacted.

While this approach has been successful in providing input to VET course content such as the Advanced Certificate in Cereal Science at Wodonga TAFE, and information input into a training package, this story also highlights the difficulty of intermittent connections in VET organisations that are in constant states of flux. Continuity of connection would ensure easier access and support the development of links that would encourage VET practitioners to be active in accessing new knowledge.

Molecular plant breeding

The connection here occurs because TAFE teachers and students attend 'hands on' workshops run by the centre. These workshops are promoted through newsletters and industry links. While welcome to attend the workshops, VET staff have not been targetted for inclusion in the technology transfer program.

Freshwater ecology

The centre for freshwater ecology has no connection with VET and does not recognise that VET is a potential user of its knowledge. Users are perceived to be the water industry managers, schools and the public. A schools project kit is currently under development. There is, however, acknowledgement among some centre staff that there is useful knowledge being generated that would be appropriate for VET. To support some flow into the VET sector centre staff in conjunction with a core partner deliver lectures to laboratory technicians on the ecology of freshwater and support field days for eco-tourism training as well as the provision of some course content.

Of interest in this case is the concept being developed in the centre of a 'knowledge broker' who synthesises and packages knowledge focussed on solving a problem being experienced by end-users. This approach reflects a traditional view of technology transfer as a linear process.

Bioproducts

This centre has been asked to provide VET staff with information that is otherwise freely available in the public domain. The centre indicates that it would consider stronger links but an approach would have to come from VET.

Australian maritime engineering

A connection occurred through the sharing of a physical resource—a catamaran used for teaching. As the centre's research was not aligned with any VET program no stronger link developed.

Eye research and technology

Though much of the research of this centre is outside the scope of VET, an online delivery capability has been developed, drawing on a VET person for advice and support.

These diverse cases show that VET is viewed within some centres as a recipient of packaged information rather than as a participant in the knowledge production process. The centre for quality wheat products and processes and the centre for freshwater ecology, for instance, hold similar views that complex innovative knowledge can be produced, packaged and simply delivered to an end-user.

Nascent connections

Nascent connections with co-operative research centres are in fact not connections, but an indication of intent. That is this category indicates centres which perceive value in a connection with VET and are looking to connect, but have had no previous connection. All the centres in this category indicate that they will need a VET connection to support their work. Rationales include that VET already has the skills to develop, manage and deliver training more cost effectively and it would be foolish to attempt to duplicate this.

Table 6.6: Nascent connections by industry sector

Industry sector	Nascent connections
Agriculture and rural-based manufacturing	
Environment	Biological control of pest animals
	Tropical rainforest ecology and management
Information and communication technology	Satellite systems
Mining and energy	
Manufacturing technology	International food manufacture and packaging science
Medical science and technology	

Nascent connections were identified in only four centres. All saw the need to become involved in varying degrees with the VET sector to develop courses and training strategies to address the flow-on of the centre's work.

In the case of the centre for satellite systems, which aims to spearhead the development of a satellite industry (see the online case study), there is at present no need for vocational training or VET involvement in the centre. However, the centre clearly articulates that as the industry develops there will be a need for VET involvement to provide support in anticipating, identifying and preparing for skills demand in the industry.

Similarly, the centre for international food manufacture and packaging science is developing innovative food packaging technologies and recognises that at present there is no food packaging industry, but in the future there will need to be a training program for this developing area. To support the introduction of new technologies it is developing, the centre has identified that VET and school teachers will need to be introduced to changing needs and methods in food packaging. To achieve this, the approach pioneered by the centre for intelligent manufacturing systems and technologies, discussed above. The centre is looking for a VET provider to develop and deliver food packaging courses.

In both the co-operative research centres for the biological control of pest animals and the tropical rainforest ecology and management the development and delivery of VET-level courses to transfer the centres' knowledge to end-users in industry will be an important part of technology transfer programs. Early involvement with VET providers is sought to ensure the timely development and delivery of these courses.

The nascent connections described here provide opportunities to develop stronger links that will support the development of a strategy to meet a future demand for skills. The strategy could include the early development of competencies, courses and appropriate delivery mechanisms through collaboration between the centres, industry training advisory boards and VET planners and providers.

Should-be connections

This category identifies centres which do not currently have any connection with the VET sector but whose research aligns with VET training capabilities. As over one-third (see table 6.2) of co-operative research centres are included in this category there is a significant opportunity for VET to explore potential relationships. However, many of these centres direct their research toward commercial outcomes that will provide their core partners with a competitive advantage. Consequently, their research outcomes are often considered commercially sensitive and in-confidence, which restricts external access.

The category accounts for 15 of the 24 centres with no current VET connections. They are spread across all industry sectors except manufacturing technology. This is perhaps indicative of a continuing perception of the VET sector as 'the tech', with a historical focus on 'blue collar' occupations.

The category is sub-divided into two groups. The 'should-be/yes' group (table 6.7 below) is spread across the four industry sectors of agriculture and rural-based manufacturing, environment, information and communication technology and mining and energy. Manufacturing technology and medical science and technology are not represented in this group, but for different reasons identified previously. The 'should-be/need investigating' group comprises cases where this is thus far insufficient information to judge whether a connection is necessary or viable, although there is a VET capability.

Reasons for the lack of connections in these groups reflect themes that have already been discussed, such as the existence of barriers discouraging connections. However, in these cases, the barriers identified work against the development of connections in the first instance. Many arise from a lack of awareness of each other in both the centres and the VET sector. Some reflect the narrow industry focus of the centre's work, weak or developing training areas in VET or an inability by VET to meet niche training demands.

Co-operative research centres with a narrow research focus include sustainable production forestry and sustainable cotton production. These centres identify VET training in rural industries as often too generic to handle the specific nature of the centre's technology and the training needs arising from it. For example, the cotton centre in the University of New England—a centre core partner—developed a Certificate 3 course to address specific cotton industry needs. VET was not approached because it was thought easier to develop the program in-house.

In the case of sustainable production forestry, VET is building its capacity in forestry training but is not aware of the technology being developed by the centre. This is also because of the commercial in-confidence nature of much of the centre's research. A similar situation exists in the centres for waste management and pollution control and Australian telecommunications. The in-confidence nature of some research outcomes is thus a barrier to early VET access to new knowledge—as well as to VET involvement in the centres.

Table 6.7: Should-be connections by industry sector

Industry sector	Should-be/yes	Should-be/need investigating
Agriculture and rural-based manufacturing	Sustainable production forestry Sustainable cotton production	Tropical plant pathology Molecular plant breeding
Environment	Waste management and pollution control Catchment hydrology	
Information and communication technology	Australian telecommunications	Enterprise distributed systems technology Sensor signal and information processing
Mining and energy	Mining technology and equipment Black coal utilisation	Hydrometallurgy Extractive metallurgy
Manufacturing technology		
Medical science and technology		Cochlear implant, speech and hearing research Cellular growth factors Tissue growth and repair

The fact that the VET sector is only now developing a capability is also restricting its involvement with centres in the environment industry sector such as coastal hydrology and waste management and pollution control, although there is a strong case for introducing new knowledge early into developing courses. This is also the case in high-technology areas, for instance the centre for enterprise distributed systems technology considers there is no role for VET because technologies being used to develop the information technology networks are specialised and not covered in VET courses.

Although the barriers mentioned are significant, more important still is the fundamental lack of awareness and understanding of each other by both VET organisations and co-operative research centres. This arguably underpins many of the barriers mentioned throughout this chapter. The fact that many centres asked us who or what is VET indicates how little is known about this sector in the national innovation system. It also illustrates that the centres rarely think beyond the immediate flow of knowledge to the perceived immediate user—a company or an industry. There is also little recognition by centres in the 'should-be/yes' group of the need for industry training that may arise from the implementation of the new technologies and other research outputs that they are developing.

One example emerges from the centre for black coal utilisation, which developed self-guided technologies for retrofitting underground mining transport vehicles. The technology was researched, developed and delivered to industry for implementation, where it was soon recognised that maintenance staff did not have the necessary skills to maintain the equipment. Consequently, the relevant industry training advisory board was engaged by industry to develop appropriate competencies for inclusion in training programs. Some formal industry training advisory board involvement in the centre might have led to an earlier recognition of the training need and expedited the introduction appropriate training at an earlier stage—thus enabling the early effective use of the technology.

Centres in the 'Should-be/need investigating' group often work close to the research end of research and development in VET relevant areas. That is, much of their work is highly theoretical and its practical applications are not immediately obvious. Several are in the medical area and as VET is only just beginning to develop this area, future capability is unclear.

The centre for cochlear implant, speech and hearing research, for example, is developing research outputs that in the future may be relevant to the audiometry courses offered in VET, but whether they will or not remains questionable. This centre does not regard VET as a potential end-user of their work. Similarly, the centre for tissue growth and repair is developing a wound care and management instructional compact disc (CD) that is being distributed to hospitals and doctors. This centre also does not regard VET as a potential user of this information, despite the relevant training it offers.

Other 'should-be/need investigating' centres are in the industry sectors agriculture and rural-based manufacturing, information and communications technology and mining and energy. Much of the research here appears to be fairly well removed from VET sector interests but this needs to be confirmed through further investigation.

Not relevant

Co-operative research centres in the 'not relevant' group are engaged in research that has no relevance to current VET sector capabilities. The two main industry sectors (table 6.8) are mining and energy and medical, science and technology. The research is extremely high level and spin-offs (theory translated into practical applications) are generally not expected for another 10 years. An example is the work of a now expired centre to improve a specific technology, which has subsequently been applied in another centre. Industry applications remain considerably down the track.

Table 6.8: Co-operative research centres with no relevance to VET by industry sector

Industry sector	Not relevant
Agriculture and rural-based manufacturing	
Environment	Antarctica and the Southern Ocean
Information and communication technology	
Mining and energy	Australian Petroleum
	Australian Geodynamics
	Clean power from lignite
Manufacturing technology	
Medical science and technology	Diagnostic technologies
	Vaccine technologies
	Discovery of genes for common human diseases
	Cardiac technology

Discussion

This chapter has highlighted the connections and disconnections between the VET sector and the centres. It has clearly demonstrated that much of the work of the centres is relevant to VET and that there is substantial potential to develop stronger links between the two that will provide mutual benefits. These benefits are already recognised where strong links exist.

However, it has also shown that the development of stronger links is inhibited by a number of different factors including mutual misunderstanding and neglect, the complex nature of the VET system and some practical difficulties in making the 'right' connections. These barriers inhibit the flow of new knowledge into VET and the timely introduction of new material into VET courses and programs.

The material strongly supports the view that if the skill needs arising from the work of the centres are to be addressed quickly—and well—then stronger connections between the VET sector and the centres are vital. This does not mean that the centres should merely consider VET as a 'recipient' of their research outcomes, but that the VET sector should pursue active participation in the centres that will also enable its organisations and people to be involved in the knowledge creation process.

Chapter 7: Making better connections

A major question that arises from the findings of chapter 6 is that given its strong connections with industry and its central and important role in industry training, why is VET not considered to be an obvious mechanism for transferring the new knowledge—and other research outputs—of the co-operative research centres into industry?

To understand the reasons, in this chapter we investigate the ideas that dominate current thinking about 'technology transfer' and some measures of their effectiveness. We also consider an alternative model that we believe provides a better explanation and which would much more clearly identify VET as capable of playing a significant role. This model also provides a constructive way of thinking that makes possible the identification, more clearly, of activities that enable technology transfer. In this regard the model recognises the VET sector as an important stakeholder in the national innovation system.

Finally, we present three models that represent best practice scenarios. These models reflect a non-linear model of technology transfer and are based on three centres and their successful arrangements with the VET sector.

Technology transfer

In chapter 5 we presented an idealised linear path of the 'research to skill requirements' process but dismissed it by arguing that experience suggests reality is much more messy and complex. Relying on such a linear model is unthinkable if we want to forecast future skill needs when research and developmental work is continuing. In this chapter, we extend this argument further by criticising the traditional notion of technology transfer as a linear process with clear boundaries and with the aim of transferring technology directly between university-based producers and industry users. Our investigations suggest that this is the notion on which centres most commonly base their technology transfer models or processes. In our view, this notion is fundamentally flawed and misrepresents real-world experiences.

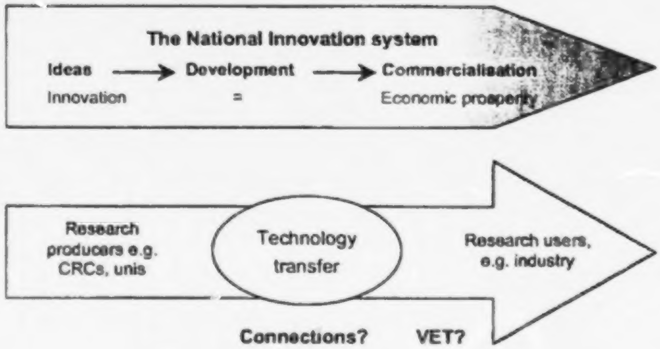
In chapter 6 the connections we explored provided further support for the view that the transfer of new knowledge is not a clean and easy process and that many factors can influence its success or failure. For instance, we noted the often ad hoc and incidental (but sometimes effective) nature of connections and that many were created by, or lost because of, individuals.

Figure 7.1 attempts to depict the dominant notion of the national innovation system that the development and commercialisation of ideas or innovations ultimately leads to economic prosperity. It shows a linear pathway from research producer to research user through a 'technology transfer' process. It illustrates VET as outside this process, leaving questions about how connections between producers and users are formed and how VET fits in.

Many centres identify practices, programs and other activities employed to support the introduction of new knowledge, products or processes created by their research into industry and the market as 'technology transfer'. Sometimes other terms are used, such as technology diffusion or research dissemination and commercialisation. However, 'technology transfer' is commonly used and understood.

Broadly speaking, this process encompasses a range of strategies that result in the utilisation of research. Carr suggests that it is 'the transfer of technology, expertise, or facilities from one person or organisation to another for the purpose of commercialisation or product/process improvement' (2000). Similarly, Odza considers it to be 'the business transactions or processes, such as patent licences or start-up companies, by which innovations are moved from one place, development stage or application to another place for a commercial purpose' (cited in Carr 2001).

Figure 7.1: The technology transfer process


The National Innovation system
Ideas → Development → Commercialisation
Innovation = Economic prosperity
Research producers e.g. CRCs, unis
Technology transfer
Research users, e.g. industry
Connections?
VET?

However, Oko and Gunasekaran (1996) make a distinction between technology transfer and technology diffusion. They argue that where technology is generated through specific research and development programs and is transferred directly to industry 'transfer' occurs. Direct transfer includes collaborative research, where formal mechanisms such as seminars, secondments or workshops become the transfer vehicles. Codifying the technology through operational manuals and research papers are also formal mechanisms. 'Diffusion' is the more informal transfer of mechanisms such as patents, licences, learning from others, education or recruitment. Here transfer becomes a consequence rather than the focus of the interactions.

This view signals that some strategies for technology transfer are less obvious than others.

The view that education is an indirect mechanism for technology diffusion is important to consider in the context of our the research findings that in the Co-operative Research Centre program VET is often not recognised as either a research user or as a technology transfer mechanism. Why is this the case?

In chapter 6, through the discussions on VET–centre connections, we identified a range of barriers to VET–centre connections. More often than not the barriers are underpinned by differences between higher education and the vocational sector which reflect the different structures of the two sectors. The overtly utilitarian focus of the VET sector often works against the establishment of personal networks between VET and higher education staff. The production focus of the training also works against the inclusion of research and development in the VET sector's work. While there is capability to engage in research and development there is no imperative to do so in the performance criteria.

Most clearly a lack of knowledge of VET by the co-operative research centres is identified as a barrier to interacting with the VET system. As the director of the centre for sustainable rice pointed out, 'the lack of understanding by management [of VET] is a significant barrier to [their] effective planning'. VET is not recognised by the centres as a user of either their knowledge or their products.

Also evident, although not to the same extent, was an elitist view held within some centres that worked against the formal recognition of VET as an integral part of the research to practice knowledge chain. A participant in one centre noted that 'the chief executive officer would consider it a diminution of the co-operative research centre's prestige to be involved with VET'. This elitism is generally subtle and may be represented in the common reply from centres that 'its not in the key indicators so there is no need to investigate'. This view ignores the realities of industry where the demands of industry growth and survival continually require cultural and socially constructed barriers to be crossed.

Richard Pickersgill (2001) noted that 'enterprises are not isolated from the environment in which they operate' because they are 'dependant to a large extent on the existence and production of 'social capital''. The dependence on trust inherent in strong networks and the synergies resulting from that trust are well documented as the future industry model, that can successfully operate in a rapidly changing economy driven by innovation. This model opposes the large multinational enterprises built in the 19th century.

Barriers to effective interaction between the VET sector and the centres are also evident in the way technology transfer is approached. Why have some centres connected while others have not? What underpins the common approach to technology transfer?

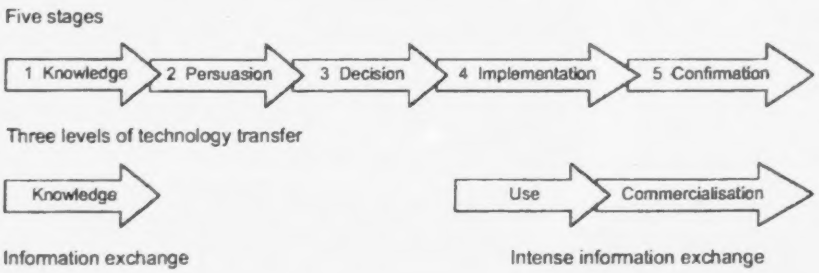
To find the answer we need to understand the underpinning theoretical framework on which the technology transfer paradigm has been built. Rogers (1995) explains:

> … the conventional view of technology transfer is that it is the process through which the results of basic and applied research are put into use. This theory implies that technology transfer is a one-way process, usually from university-based basic research to individuals in private companies who develop and commercialise the technological innovation'. (p.140)

Diffusion theory

Rogers (1995) championed this theory from the late 1950s although he considers it still does not address satisfactorily the innovation transfer process. This linear one-way approach assumes that the receiver of the innovation is a passive recipient rather than an active seeker and participant in the process (Baptista 1999). However, Rogers argues that technology transfer should be seen as a communication process—a two-way exchange of information that can occur at three levels: knowledge; use; and commercialisation (1995). He aligns these three levels with his 'diffusion of innovations' model in which, it is argued, are five stages (see diagram 7.2) through which individuals or a decision-making unit pass before adopting an innovation.

Figure 7.2: Roger's five-stage innovation decision process



Source: Adapted from Rogers (1995, p.163)

Rogers recognises that technology transfer requires complex exchanges of information between the innovation or technology source and the user at the second 'Use' stage (see figure 7.2). The exchanges become even more intensive during the 'Commercialisation' phase of an innovation. He suggests that the intense level of exchange is often underestimated with the result that failure or protracted difficulties and delays often occur.

This linear, communication-based approach, while recognising the need for complex and intense communications, ignores other dimensions. Its focus on two entities, the 'innovator' and the 'receptor', ignores other factors such as the physical and educational resources that are necessary for technology transfer, and the political, personal, institutional social and cultural influences that affect the outcome of a technology transfer effort.

To contextualise Roger's position on technology transfer and the influence that this model has on much of current thinking it is necessary to go back to the early research on the adoption of new ideas. The single most influential innovation adoption study, the one considered the genesis of innovation diffusion studies, was carried out by Ryan and Goss (1943) more than five decades ago and concerned the diffusion of hybrid corn among farmers in Iowa. This study set the fundamental framework that is used today.

The American concept of 'agricultural extension', that is, programs to aid the diffusion of information and new practices to farmers, was formalised in 1914 and later influenced the American 'agricultural revolution' in the 1950s and 60s. This model was adopted in other countries including Australia, where government agricultural services have provided 'extension services' for many years to inform and assist in the dissemination of information and the adoption of new agricultural products and practices. Indeed this term was used by many in the agricultural-based centre to describe their activities.

Many attempts have since been made to apply the model, unsuccessfully, in areas other than agriculture and including education, public transport and family planning (Rogers 1995). Though they were unsuccessful, the model suffered little criticism for two decades until the 1970s and continued to be regarded as best practice for technology transfer. Although some new thinking began to emerge in the 1970s, this 20-year period of significant interest left its mark on current thinking about, and practice of, technology transfer.

Evidence of this approach in the Co-operative Research Centre program can be found in the way knowledge is packaged in texts, seminars, conferences and extension like services of knowledge brokering. These efforts provide generally workable and accepted solutions within higher education but tend to ignore other possibilities for the transfer of knowledge into the industry sector.

In the 1970s serious criticisms of the diffusion theory emerged to expose a fundamental flaw in the model. Critics pointed to a 'pro-innovation bias' evident in that there were few studies which used the model to explain failed innovation diffusions. In addition, in cases where the model was used to explain failed programs, it tended to blame individuals for not adopting the innovation, rather than the diffusion processes themselves. This shifted responsibility for failure away from the innovation or its originator and onto the potential adopter.

Another criticism is that the diffusion model is concerned with a simplified cause and effect interaction for adopting new ideas. It identifies factors that work for or against the adoption of an innovation. These factors are analysed after the event to explain what happened. However, they do not enable predictions to be made or make it possible to clearly understand the process. It tends to generalise and make the process abstract.

Actor-network theory

More recent studies in science, technology and society and in particular actor-network theory have 'shed light on the situated and intensely practical nature of the mechanisms involved in the transition of technology' (McMaster, Vidgen & Wastell 1997).

Actor-network theory was initiated by Bruno Latour (1987) and Michele Callon (1986) as they sought to understand interactions between science, technology and society. Unlike diffusion theory, actor-network theory calls us to look beyond the human participants in change and to look more broadly at other entities that affect the outcome of the change process. In this regard it views innovation not as a linear process moving along a predictable path with predictable factors, but as a more messy political process where a collection of actors influence the direction the innovation takes, either toward its successful implementation or its failure.

It is in the construction of an actor-network through the 'enrolment' and 'alignment' of actors, that is, to interest actors in sharing a common focus with other network actors, that the network builds momentum, pushing forward the introduction of a new technology, product or process. Through the process of 'translation', each actor contributes its own resources to the shape, form and function of the network and its ultimate stabilisation as a 'fact'. We have seen this process in the development of strong relationships between a co-operative research centre and VET, where as each contributes to the relationship the form and function of that relationship develops according to the interests and negotiations of both parties. The final relationship ultimately becomes a fact, or in actor-network theory terms, a 'black box'.

Resistance to the construction of the network can be built by opposing actors who may also build an actor-network 'enrolling' and 'aligning with' other actors or actors from the opposing network, against the technology. The essence of actor-network analysis is to recognise and understand the often subtle politics at play and influencing the change process. This recognition also provides a model that used proactively can be used to identify barriers not obvious in the factor model of diffusion.

Before providing examples of how we see actor-networks in operation in the technology transfer process there is a need to briefly explain the actor-network theory concept of the actor. Unlike social networks, which consist only of individuals who communicate and have influence through their actions, the actor-network consists of all objects of influence within a network. An actor in this sense then, is any entity, human or non-human (e.g. institutions, financial resources, equipment, text, media, training courses, etc.) that are able to influence the acceptance or rejection of a technology.

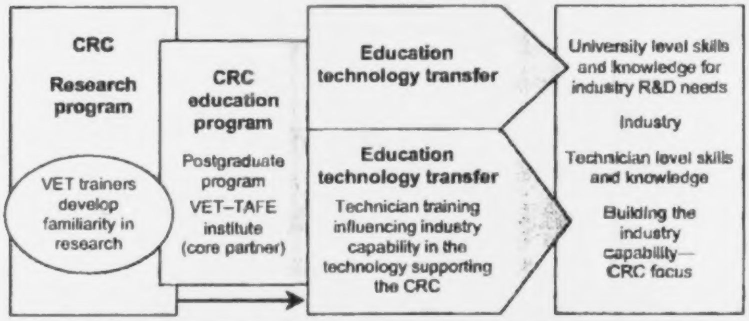
To understand the interactions that characterise technology transfer, actor-network theory calls us to trace the complex interplay of influences that impact upon this process, to follow the actors as they influence or inhibit the flow of technological information. While this research and its data collection were not framed by the concepts of actor-network theory, through interviews and collection of documents and industry data we have done this.

In the case of photonics, an analysis using actor-network theory shows that in the centres' technology transfer program a broad range of actors influenced the take-up of photonics technology. These included market demand, current producers, production capability, and availability of skilled labour. As each was investigated further, actors were identified within these broad areas. For example, in assessing skilled labour demands a severe shortage was identified. Here the question of how this actor (skilled labour shortage) could be neutralised called for other actors to be 'enrolled' into the network. VET, as an industry trainer was enrolled to develop courses and provide the training, strengthening the photonics network.

In 'enrolling' NSW TAFE as an actor, the Australian photonics centre not only increased its support but also further strengthened the network connection. It did this by using another actor, the core-partner relationship, which as a structural, binding connection is far more difficult to break than an informal connection.

Another important actor is tacit knowledge, or knowledge that is not codified in texts and which can be passed informally through close interpersonal connections between, in this case, researchers and those who train technicians. This transfer of tacit knowledge is considered critical to the successful transfer of knowledge (Nelson & Winter in Baptista 1999). This tacit knowledge, like any important actor needs to be 'enrolled' and aligned to support technology transfer. The photonics centre achieved this through involving VET trainers in its research program, passing on the as yet uncodified knowledge. At the same time it developed strong structural conduits for the flow of knowledge for the photonics industry development—the focus of the centre. Figure 7.3 gives a representation of this actor-network.

Figure 7.3: Australian photonics technology transfer for a new industry


CRC
Research program
VET trainers develop familiarity in research
CRC education program
Postgraduate program
VET–TAFE institute (core partner)
Education technology transfer
Education technology transfer
Technician training influencing industry capability in the technology supporting the CRC
University level skills and knowledge for industry R&D needs
Industry
Technician level skills and knowledge
Building the industry capability—CRC focus

Knowledge is transferred through actors 'enrolled' and strongly aligned to the aim of the co-operative research centre

A further example of successful technology transfer can be found in the Co-operative Research Centre for Viticulture. Although viticulture is a well established industry it has relied heavily on the rapid introduction of new knowledge and practice to make it a global leader in market responsiveness and quality.

The inclusion of the Wine Industry National Education and Training Advisory Committee as a core partner to manage the viticulture centre's education and training program recognises the importance to the industry of vocational training. The wine industry advisory committee as an actor represents the industry's network and its needs, influencing the work of the centre to respond to industry training needs.

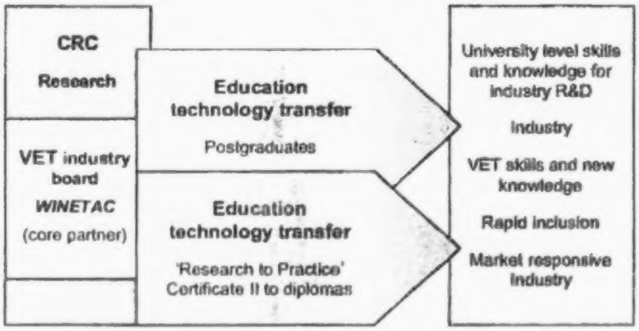
The committee's 'Research to Practice' set of workshops is also an actor, educating and aligning the industry focus on market response through technology.

The structural relationship between the centre and the advisory committee, like the photonics centre, strongly aligns and strengthens the inclusion of the VET sector as an actor, aligning it to the purpose of the centre—to develop the industry skill base and to rapidly introduce new technologies. Figure 7.4 shows this actor-network.

Actor-network theory also provides a way to explain the failure of a technology-transfer process to identify key actors that would support introduction of technology.

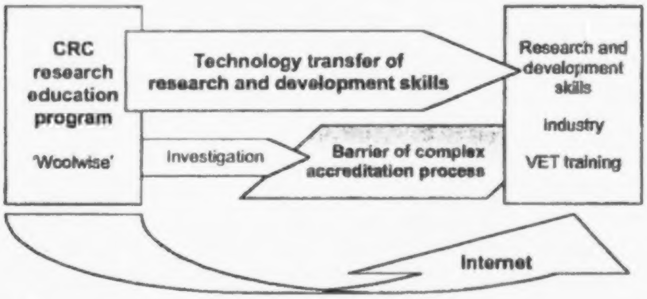
An example of this is found in the Co-operative Research Centre for Premium Quality Wool where it was recognised that their 'Woolwise' training resources would be a valuable resource to the VET sector and should be incorporated into VET-based courses. However, it was concluded that this would be a 'difficult' and 'tedious' project and that 'the hurdles (were) too difficult for gaining accreditation'. Here the actors of 'complex processes of development and accreditation in VET successfully resisted the development of a network that enabled the inclusion of those training resources in the VET sector. Had another actor been enrolled to neutralise the effect of the 'complex processes', such as a VET institution to take on the role of accreditation, the 'Woolwise' training resources might have been successfully integrated into VET training. Instead the centre, still wanting to enable access to their technology, 'enrolled' another actor, 'the internet', in order to diffuse their knowledge to the VET sector, albeit less directly. This network is represented in figure 7.5.

Figure 7.4: Co-operative Research Centre for Viticulture actor-network


CRC
Research
VET industry board
WINETAC
(core partner)
Education technology transfer
Postgraduates
Education technology transfer
'Research to Practice'
Certificate II to diplomas
University level skills and knowledge for industry R&D
Industry
VET skills and new knowledge
Rapid inclusion
Market responsive industry

In this actor network WINETAC as an industry body representative 'enrols' the co-operative research centre education program and the VET system into that program to meet the wine industries' needs

Figure 7.5: Actors as barriers in the Co-operative Research Centre for Premium Quality Wool


CRC research education program
'Woolwise'
Technology transfer of research and development skills
Investigation
Barrier of complex accreditation process
Research and development skills
Industry
VET training
Internet

While these explanations have been necessarily simplified and brief it can be seen that actor-network provides a more useful model for understanding the complex transactions that occur in technology transfer. Unlike the traditional diffusion model an actor-network approach calls for a search for all the actors and identifies the relationships between them and their stakeholders. In analysing the technology transfer networks of a co-operative research centre we can begin to understand better the importance of previously obscure entities such as the VET sector and its role in the centre's program.

What we propose here is a rethinking of the notions surrounding technology transfer. This will lead to a more informed understanding of just who the users of a centre's output are and the importance of the supply-side responsibility in seeking out the best actors to 'enrol' in their technology transfer 'actor-network'. This understanding would lead to a recognition of the importance of the VET sector in supporting the timely and efficient introduction of new knowledge into the national innovation system to support the production of goods and services based on new technology.

Beyond co-operative research centres

While we have focussed on the centres' program in this discussion, other research and development efforts exist under the national innovation system banner. The observations we have made apply equally to these efforts. The involvement of a VET organisation in the development or introduction of a new technology can provide significant support to the process.

For maximum effectiveness, the VET sector needs to seek out partnerships with the research and development sector to build their capability to respond to new technologies. For example, NSW TAFE Industry Partnership Centre has had a longstanding relationship with the Warren Centre and involvement in the Smart Card and photonics industry forums. This has placed NSW TAFE in a strong position to gather information relating to these industries and to prepare timely training. VET involvement can also provide support for business development, for example the 'TAFE Card' program has provided an important a test project for the smart card industry.

Similarly, the national innovation system 'actor-network' also needs to identify the actors that will strengthen the innovation network and support the rapid translation of technology into commodities. If VET is identified among them and as a user of new technology knowledge, the advantages for the national innovation system will include:

- timely skills development in new and existing industries
- better knowledge transfer into the training system to support industry development
- timely anticipation of training needs
- a reduction in the likelihood of skill gaps or shortages
- highly skilled national workforce
- a culture of innovation in the VET sector.

Best practice, three models

We have discussed how actor-network theory provides an explanation of why and how knowledge flows or does not between the VET sector and centres. We have also briefly discussed this in the broader context of the national innovation system. We have shown co-operative research centre technology transfer models that have been successful. An important question remains: Is there a single best practice model for VET engagement with co-operative research centres or the national innovation system?

In our view, based on the findings of the study, to identify one best practice model is to ignore the diversity of research and development work that occurs within the national innovation system.

The research has shown that where good practice was evident the following actions had been taken. The centre had:

- involved VET at a time that maximised the capability of VET to support the industry (early enough to allow course development and accreditation)
- supported the rapid flow of new knowledge and practice into VET (openly encouraged VET personnel to interact with the centre)
- had a structured agreement with defined responsibilities for both the VET sector and the centres.

The VET partner:

- recognised that there would eventually be a return on investment
- provided support for staff to interact with the centre
- initially provided and maintained a single point of contact
- took responsibility to address the complexity of VET systems for the centre

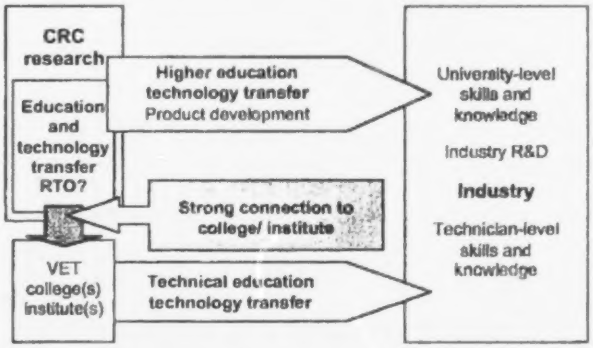
- TAFEcard is the NSW TAFE student ID card which has moved from magnetic stripe technology to 'Smartcard' or microchip technology.

Three models drawn from the operation of three centres show the approaches taken to address these points. These three centres are also presented as case studies online.

Co-operative Research Centre for Renewable Energy

In the first model, based on the centre for renewable energy and shown in figure 7.6, the relationship developed from mutual interests of individuals connecting the VET teaching area with the centre's research. The centre now recognises the role VET plays in transferring centre research into practice. The current link with a college limits a more national coverage and the centre is moving towards VET status as a registered training organisation that will allow it to develop nationally accredited courses for the use by the VET providers. This model takes an initial involvement with a VET provider giving familiarisation with the VET system then places the centre at the heart of course development. The advantage in this model is the ability for the centre to familiarise itself with the VET sector at an informal level before determining how to proceed with a VET connection. A disadvantage of this model is that a long-term commitment and involvement in the VET sector is needed to justify the efforts to become a registered training organisation. This may take time and effort from research and development. Of course the limited lifespan of the Co-operative Research Centre program funding may also impede this goal, thus increasing the reliance on other actors.

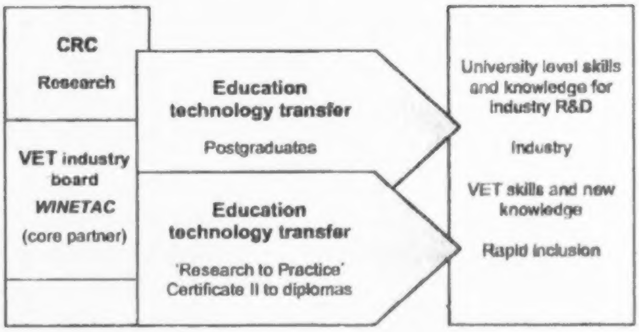
Figure 7.6: Best practice model #1


CRC research
Education and technology transfer RTO?
Higher education technology transfer
Product development
Strong connection to college/ institute
VET college(s) institute(s)
Technical education technology transfer
University-level skills and knowledge
Industry R&D
Industry
Technician-level skills and knowledge

Co-operative Research Centre for Viticulture

In the second model, shown in figure 7.7, the industry is mature and has embedded its vocational education arm into the centre in order to manage the delivery of research output into the industry. The model places the industry core partners at the front end of the centre with the research effort focussed on its utility and return on investment. This model provides rapid introduction of new technologies into the industry workforce. However, this type of industry control can lead to research and development, and training that is focussed on the needs of large enterprises, possibly neglecting the needs of smaller businesses.

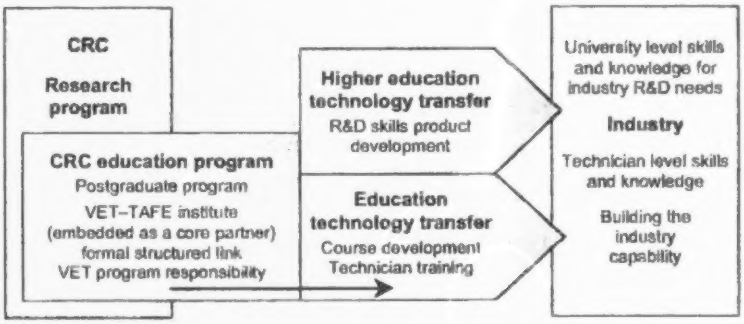
Figure 7.7: Best practice model #2


CRC
Research
VET industry board
WINETAC
(core partner)
Education technology transfer
Postgraduates
Education technology transfer
'Research to Practice'
Certificate II to diplomas
University level skills and knowledge for industry R&D
Industry
VET skills and new knowledge
Rapid inclusion

Australian Photonics Co-operative Research Centre

The final model is based on the Australian Photonics Co-operative Research Centre which, in spearheading the development of a new industry and industry workforce, had no industry or vocational education base to work from. An early involvement with the VET sector led to NSW TAFE's involvement in the management and responsibility of the centre's industry vocational education needs. This provides us with a model that allows the centre to maintain its focus on research and development while the VET relationship provides the centre with a specialist arm to address the training needs.

Figure 7.8: Best practice model #3


CRC
Research program
CRC education program
Postgraduate program
VET–TAFE institute
(embedded as a core partner)
formal structured link
VET program responsibility
Higher education technology transfer
R&D skills product development
Education technology transfer
Course development
Technician training
University level skills and knowledge for industry R&D needs
Industry
Technician level skills and knowledge
Building the industry capability

Summary

In this chapter we suggest that current models of technology transfer provide a narrow view of the technology transfer process. This view necessarily limits the recognition of the less obvious users of technology. We argue that this, along with cultural and social considerations including a subtle elitism, contributed to VET being excluded. It has also been shown that the thinking behind much of current technology transfer practice is flawed, being based on thinking that does not represent the true politics and the messiness of technology transfer. Another way of thinking has been put forward that more closely reflects the reality of technology transfer. There are other models that more closely reflect the reality of technology transfer. We have also provided best practice models that represent three ways in which VET and the co-operative research centres can connect to maximise the benefits and capabilities of both parties.

Chapter 8: Reviewing the journey ... and looking to the future

In this VET journey into the national innovation system we set out to learn about the skill needs of new industries and the ways in which the VET sector could best respond to them. Given the limitations of time and other resources our study was confined to only one part of the national innovation system—the Co-operative Research Centre program. Along the way we have investigated a number of different aspects of the co-operative research centres. We have:

- examined the centres' research programs to identify their relevance to the current capabilities of the VET sector
- identified the likely outputs of these research programs, the industries in which they are likely to be most useful and any possible skills requirements that might arise as the outputs are applied or put into production
- explored the commercialisation and dissemination programs of the centres and whether new industries are likely to emerge from their work
- documented the links—or lack of links—between the centres and people and organisations in the VET sector, their consequences and the main barriers to stronger links.

These activities have been undertaken in a survey of relevant literature and of the centres' annual reports, a telephone survey of centres, case studies in ten centres and a further case study of a group of high technology companies.

From our journey we have learned that new industries go through three main stages of development, each of which has different skill needs. The VET sector's role is potentially strongest in the third stage, when medium-level technical skills are sought after to operate tools, equipment and systems and to install and maintain products. In the first stage, the emphasis is on high-level skills for research and development. In the second stage, management skills are important to achieve successful market entry.

Among the co-operative research centres we studied, new industries are already apparent in photonics and in the environmental areas of renewable energy, waste management and de-salinisation ('saltonics'). A future new industry is likely in satellite systems. In addition, a number of the centres are working toward the re-creation of existing industries. These include several that are working towards re-forming existing industries on a sustainable basis, particularly in agriculture and tourism. Further potential for new industries exists also around the products, tools and processes that will be the outcomes of the centres' research and development programs, for example agricultural machinery and diagnostic systems.

Whether oriented primarily to a new or to an existing industry, most centres are working to create innovations such as new technologies, processes, tools, equipment or products. Some of these innovations will lead to requirements for some new skills, or contextualised skills, as they are applied in industry or enter production. The VET sector could play a part in meeting at least some of these skill needs, particularly where low to medium-level technical skills are required.

However, not all innovations will lead to changed or new skill requirements. A new product, for instance, may simply add a line to an existing suite of products. Manufacturing, installing or servicing this product might require only existing skills. The same thing could be true for a new tool, process, system or other piece of equipment. New or updated skills will be required only where there is a significant difference between the innovation and whatever it replaces or complements.

Some innovations are competency-destroying because they replace, rather than amend, whatever already exists. This is the case with some new technologies, and in these cases skill requirements may change substantially. Sometimes a new tool or system will simplify a task that previously could be performed only by experts. These innovations free up experts for more creative work and enable workers with lower level skills to take on tasks that in the past required more expertise. This technician will then require some training to perform the task effectively.

It is important when assessing whether new or upgraded skills will be needed as a result of the adoption or implementation of an innovation to consider the particular characteristics of the innovation carefully and to compare it with what already exists. In some cases workers may only need to make minor adjustments. In others, more radical initiatives will be required.

The VET response

Not all skill needs arising from the innovations created by the co-operative research centres require a formal response from education and training systems. In the case of the existing industries that are connected with the centres, as long as the number of workers required to have new skills is small, the centres themselves are often able to meet the demand for training/re-training through the industry seminars and workshops that are part of their education and training programs. However, when many workers with new skills are needed, the centres do not have the capacity to meet demand and look to others, such as educational institutions and systems, for support.

The time required to develop appropriate programs and materials and the capabilities of staff to deliver new courses means that planning to deliver VET should ideally start well in advance of the point where the training is required. In the case of new industries, this will be well before the industry reaches the third of the three main stages of development. This possibly lengthy process would be expedited if the VET sector were familiar with the work being done in the centres and its potential to create new skill requirements and also if the centres recognised the interest of the VET sector in their work and its outcomes and acted to include it in their activities.

Currently, the new knowledge created in the co-operative research centres does not always reach the VET sector. There is no systematic process supporting the flow of information between the two and the links that do exist are often weak or informal. Thus, centres might be unaware of VET sector interest in what they are doing and knowledge of the work of the centres may be uneven in different parts of the VET sector—even where this work is likely to lead to innovations that will clearly require a VET response.

Where the links between the VET sector and the co-operative research centres are strongest, benefits flow to both sides. For the centres, connections with the VET sector provide access to new networks and extensive experience in working with industry. As new skill needs arise, they can be dealt with more quickly and effectively. VET links can also bring in specialist expertise and enable access to specialised equipment and other facilities. For VET organisations, benefits from connecting with a centre include additional opportunities for staff personal and professional development through participation in research and development, or in the centre's education and training program. The organisation will gain access to the new knowledge that it needs to ensure that its teaching remains up-to-date. It will have information that will enable it to identify new opportunities for fee-for-service provision.

The places where strong links currently exist provide the basis for constructing effective models for VET–co-operative research centre interaction. While no single model is suitable for all occasions, each demonstrates some 'best practice' features that others could usefully emulate. None of these connections is working perfectly. In each case some difficulties have arisen—usually through a lack of knowledge or misunderstanding (e.g. the photonics industry and its experience with preparing competencies for inclusion in a training package). However, in each case also the benefits of the relationship are clear.

Future objectives

Based on the findings of this project, the development of stronger links between the VET sector and the co-operative research centres should be pursued as beneficial to both and to the industries they serve. Ideally, the centres should not merely consider VET as a 'recipient' of their research outcomes, although recognising the VET sector's interest in their work would be an advance in some cases. This would limit the benefits that could be derived from the connection and would not support timely attention to new training needs. Rather, the VET sector should participate where possible and appropriate in the activities of the centres—in the knowledge creation process as well as in the centres' commercialisation and dissemination and education and training programs. Only through the mutual knowledge and understanding that will arise from a close relationship of this sort will the full range of benefits be achievable.

Therefore, an objective we propose for the future is ***to build and strengthen the links between the VET sector and the co-operative research centres in order to:***

- improve the timely flow of new knowledge from the centres into the VET sector to support planning for the delivery of VET to meet the skill needs arising from the adoption of centre-created innovations in existing industries and the creation of entirely new industries
- enable the centres to make use of the strong VET links with industry (including in the design and delivery of training), the facilities of VET sector organisations and the skills and expertise of VET personnel
- promote teacher currency in VET through professional development opportunities for VET personnel within the centres.

A commitment by both the VET sector and the co-operative research centres will be needed to achieve this objective and will require action by many people and organisations. A leadership role taken in the VET sector by the Australian National Training Authority, state and territory training authorities and some registered training organisations would assist this process. There is also considerable potential for industry training advisory bodies to play a stronger part in improving the flow of knowledge between centres and VET planners and providers, particularly in the case of existing industries.

Specific suggested strategies include:

- The co-operative research centres could pursue stronger links with the VET sector by:
  - extending existing education and training programs to provide some re-training workshops/seminars/short courses specifically for VET managers and teachers and industry training advisory board personnel
  - extending existing programs for secondary students to VET students
  - opening up opportunities for VET graduates to increase their knowledge and skills through participation in education and training programs
  - actively seeking out VET organisations and personnel who could contribute to the work of the centre, for example, as board members or as members of a research team, to assist in the delivery of industry programs
  - identifying VET organisations that would be likely end-users of the research
  - drawing on VET expertise in management and commercialisation.

Key performance indicators could include:

- VET organisations as associates of the co-operative research centre
- individuals from the VET sector as centre board members

  - VET participation in research, commercialisation/utilisation programs and education and training programs
  - industry training advisory board participation/contact
  - provision of re-training for VET teachers/trainers as a function of the co-operative research centres' education and training programs
  - programs/activities for VET students and graduates.

- VET sector organisations could pursue stronger relationships with the co-operative research centres by:
  - providing advice and information to centres that will enable them to navigate the VET sector and forge strong and effective VET links
  - identifying where a centre is undertaking work relevant to its own work and approaching this centre with some suggestions for collaboration or co-operation
  - supporting staff to take up professional training/development opportunities within the centres
  - supporting re-training programs for VET graduates, including through programs in, or in conjunction with, co-operative research centres.

More specifically, registered training organisations could:

- identify their areas of strength and seek collaborative research links with co-operative research centres working in these areas
- investigate the potential for joint provision of education and training programs with centres
- investigate opportunities in the centres for the professional development of their staff
- investigate opportunities to provide professional development for centre staff, for example, in management and commercial skills.

Further research

This project has highlighted some gaps in knowledge and understanding that could be addressed through further research. These include:

- The contribution of research performed in the VET sector to the national research effort and to innovation in Australian industry: now and possibilities for the future.
- The efficiency and effectiveness of current mechanisms for introducing new knowledge, skills and content into the VET sector.
- Problems and prospects in maintaining the currency of training package competencies, particularly in relation to new and evolving industries and new skills.
- Industry innovation and its implications for teacher currency in VET.
- The costs and benefits of participation in the national innovation system by VET organisations at the system and provider levels.
- The scope and functions of industry training programs in the national innovation system and implications for the funding, provision and delivery of VET.
- The VET/higher education interface: problems of culture and bias, their effects and how they are being addressed.
- The allocation of public funding for VET provision to meet the needs of new industries: current problems and future possibilities.
- Improving the technology capability of the VET sector: prospects and possibilities.

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Appendix 1

List of co-operative research centres, by number

01 Advanced Composite Structures
02 Australian Maritime Engineering
03 Materials Welding & Joining
04 Polymers
05 Molecular Engineering & Technology
06 Bioproducts
07 Intelligent Manufacturing Systems & Technologies
08 CAST Metals Manufacturing (CASTMM)
09 International Food Manufacture & Packaging Science
10 Robust & Adaptive Systems
11 Enterprise Distributed Systems Technology
12 Australian Photonics
13 Sensor Signal & Information Processing
14 Australian Telecommunications
15 Advanced Computational Systems
16 Research Data Network
17 Satellite Systems
18 Mining Technology & Equipment
19 Extractive Metallurgy
20 Australian Petroleum
21 Hydrometallurgy
22 Australian Mineral Exploration Technologies
23 Clean power from lignite
24 Australian Geodynamics
25 Landscape Evolution & Mineral Exploration
26 Black Coal Utilisation
27 Australian CRC for Renewable Energy
28 Plant Science
29 Tropical Pest Management
30 Sustainable Production Forestry
31 Legumes in Mediterranean Agriculture
32 Tropical Plant Protection
33 Hardwood Fibre & Paper
34 Viticulture
35 Wool
36 The Cattle & Beef Quality
37 Aquaculture
38 Sustainable Cotton Production
39 Food Industry Innovation
40 Sustainable Sugar Production
41 Quality Wheat Products & Processes
42 Molecular Plant Breeding
43 Sustainable Rice Production
44 Waste Management & Pollution Control
45 Soil & Land Management
46 Antarctica & the Southern Ocean
47 Catchment Hydrology
48 Biological Control of Pest animals
49 The Great Barrier reef world heritage area
50 Freshwater Ecology
51 Southern Hemisphere Meteorology
52 Tropical Rainforest Ecology & Management
53 Tropical Savannas
54 Conservation & Management of Marsupials
55 Water Quality
56 Weed Management Systems
57 Sustainable Tourism
58 Tissue Growth & Repair
59 Cellular Growth Factors
60 Eye Research & Technology
61 Biopharmaceutical Research
62 Cochlear Implant, & Hearing aid innovation
63 Cardiac Technology
64 Vaccine Technology
65 Diagnostic Technology
66 Aboriginal & Tropical Health
67 Discovery of Genes for Common Human Diseases

Appendix 2

List of consultations

John Boyd	Co-operative Research Centre Secretariat, Department of Industry, Sciences and Resources
Steven Byrne	Manager, new technologies and markets, National Office for the Information Economy
Marea Fatseas	Director, projects, Research Branch, Higher Education Division, Department of Education, Training and Youth Affairs
Peter Huta	Manager, Education Strategies, Government and Community Strategy Strategies, National Office for the Information Economy
Alan Jones	Manager, Innovation Systems Research, Innovation and Science Division, Department of Industry, Sciences and Resources
Lucio Krbvac	Department of Education, Training and Youth Affairs
Paul Mills	Higher Education Division, Department of Education, Training and Youth Affairs
Michelle Scott	e-commerce, National Office for the Information Economy
Peter Sesterka	Manager, Emerging Industries, Services and Emerging Industries Division, Department of Industry, Sciences and Resources

Appendix 3

Survey of annual reports pro-forma

Title of the CRC:	
Industry *(ABS classification)*:	
Website?	
Background information:	
For how many years has the CRC existed in its current form?	
Partners:	
Universities:	No: With TAFE divisions: No Names Without TAFE divisions: No Names
Enterprises:	No: Names:
Government Departments:	State departments no: Names: Federal departments no: Names:
Research Organisations	No: Names:
VET Registered Training Organisation:	No: Names:
Other partners:	No: Describe:
Education Contact	Name: Phone:
Commercialisation contact	Name: Phone:

Intellectual Property and Commercialisation	
Will any of the CRCs research product be ready for commercial transfer within 3 years?	
Does the CRC have a formal strategy for commercialising its IP?	Yes/No

How long has this strategy been in place?

If yes, which of the following elements are included in this strategy? (indicate all)

	Registration of intellectual property
	Commercialisation through partner enterprises
	Commercialisation through spin-off enterprises
	Commercialisation through university commercialisation arms?
	Other elements (list)

If no:

Is a strategy under development?.................................... Yes/No

How does commercialisation occur?

Does not occur

Has not occurred yet but expected

Not indicated

Other: *(describe)*

Does the CRC have a process for developing spin off companies?

Is a spin off company approach appropriate for this technology or new knowledge?

Is the Commercialisation entirely by industry partner?

Is industry partner ASX listed, private or OS multinational or Multinat subsidiary?

Did the CRC register any patents during the year described?		No: None Not known
Type and no of patents:	Systems or processes:	
	Equipment/machinery/tools:	
	Other (describe):	

Direction of work

Is work of the CRC directed to:

- The development of new or improved systems or processes?
  - Very little
  - Some
  - Considerable
  - Not clear
- The development of new or improved equipment, machinery or tools? i.e. technologies with high impact – (new components or widgets)
  - Very little
  - Some
  - Considerable
  - Not clear
- The deepening of knowledge? (research for research)
  - Very little
  - Some
  - Considerable
  - Not clear

Where are these developments expected to have an impact?

- Mainly within existing industries
- Within both existing and new industries
- New research opportunities within the CRC
- Mainly within new industries
- Other (explain)
- Not known

How are these developments expected to affect skill needs?

- No change in skill needs
- Increase the need for existing skills
- Increase the need for existing skills and create a need for some new skills
- Reduce the need for existing skills and create a need for some new skills
- Other
- Not known

If a need for new skills is anticipated, what is its extent expected to be?

- Very little
- Some
- Considerable
- Not known

Education, training and dissemination	
Which of the following activities does the CRC engage in: (indicate all)	
	Staff development
	Higher degree teaching or research
	Undergraduate teaching or research
	Teaching at Diploma level or below
	Short course provision
	Demonstration for schools at a senior level (yrs 11 and 12)
What other education and training activities are conducted:	

Connection with the VET sector:

Describe any formal or informal connections with the VET sector indicated in the report:

In house company parent

Private providers

Other TAFE

Graduate Schools

Off shore

Appendix 4

CRC phone interview protocol

Confirm CRC structure findings			
Core – any VET ? Affiliates/participants – any VET			
Confirm R and D findings			
Any VET in any R and D			
Confirm Commercialisation processes			
Any VET current ? Any VET possible ?			
Confirm diffusion and dissemination findings			
VET as recipient VET as mechanism Describe			
Confirm E and T findings			
Any VET at all informal project based			
description of education and training and vet	Inward	Semi open	Dynamic
What about other possibilities			
PD for TAFE staff as target of industry upgrades			
Students targeted for new knowledge			
VET partner for mainstream courses –training packages			
ITABS			
Other RTOs			
Is CRC an RTO ? Are they interested in becoming one?			
Why No VET in the past ?			
Issues of relevance			

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